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FRAGMENT HAZARD INVESTIGATION PROGRAM

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Prepared for
DEPARTMENT OF DEFENSE
EXPLOSIVES SAFETY BOARD

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cont.

In order to simplify the problem, various projectile configurations based on the standard storage pallet were simultaneously detonated in a series of fragmentation test arenas. The projectile configurations and the fragmentation test arenas are discussed and an analysis of the data is presented. A fragmentation model characterizing the simultaneous detonation of a pallet of 155-mm projectiles is developed and verified with the arena test data. The model implies that in establishing quantity-distance requirements more emphasis should be placed on the munitions stack configuration rather than the total amount of explosive. These experimental findings are compared to current quantity-distance requirements for the safe separation of inhabited buildings from mass-detonating hazard materials. The comparison shows that for simultaneously detonated stacks there are storage configurations which have a potential for producing far-field fragment hazards in excess of these present quantity-distance requirements.



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FOREWORD

This document presents the efforts expended by the Naval Surface Weapons Center, Dahlgren to generate data to improve quantity-distance standards for handling and storage of stacked munitions. The hazard classification under investigation is the Mass-Detonating Hazard Materials (Class 1, Division 1).

The work was accomplished for the Department of Defense Explosives Safety Board (DDESB) under Military Interdepartmental Purchase Requests CE-NSWC-75-2 of 22 April 1975, CE-NSWC-76-1 of 9 March 1976, and CE-NSWC-77-1 of 24 March 1977. The technical monitor of the program for the DDESB is Dr. T. A. Zaker.

This report has been reviewed and approved by Mr. Roy Shank, Head, Environments Division.

Released by:

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Engineering Department

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METRIC COVERSION TABLE

<u>Multiply</u>	<u>by</u>	<u>To Obtain</u>
Feet	30.48	centimeters
inches	2.54	centimeters
grains	0.0648	grams

INTRODUCTION

This report covers a portion of the Fragment Hazard Investigation Program sponsored by the Department of Defense Explosives Safety Board (DDESB). The purpose of the program is to provide the DDESB with the necessary fragmentation data to improve the quantity-distance (QD) standards of Reference 1. Reference 1 specifies the safe and efficient storage of stacked munitions according to specific hazard classifications. The hazard class under investigation is the Mass-Detonating Hazard Materials (Class 1, Division 1). Mass detonating items are those for which instantaneous explosion or detonation of the entire quantity may be expected in the event of an accident. Munitions of this type consist of: bulk explosives and certain propellants, mines, bombs, demolition charges, torpedo and missile warheads, rockets, palletized projectiles loaded with TNT or COMP-B, 8-in. and larger high capacity projectiles loaded with explosive "D" and other munitions listed in Reference 2.

In the event of an accident, personnel are exposed to hazards from three kill mechanisms; blast, fragmentation, and debris. Present hazard classification of mass detonating ordnance during manufacturing, transportation and storage is based on quantity-distance standards which relate the net weight of explosive to safe stand-off distances for personnel, buildings, and highways. The safe stand-off distances are proportional to the cube root of the explosive weight. By relating stand-off distances to explosive weight, the acceptable risk to a given target is based on the peak blast overpressure produced by a weapon. However, the distance to which fragments are projected does not follow the same scaling rules as does air blast. Thus, defining an acceptable air blast overpressure does not necessarily result in an acceptable fragment hazard.

The NSWC/DL was instructed by the DDESB to conduct tests on the Army M107 155-mm projectile (TNT-loaded) in order to permit comparison of the results with those of previous tests of large stacks of the same projectile. As part of the DDESB program the NSWC/DL was tasked to perform arena fragmentation tests of various projectile stacking configurations and to conduct supporting analytical studies. Data from these tests will be used to develop analytical tools to produce improved safe distance quantification data and curves. The program was divided into two phases with testing and supporting analytical studies to begin in July 1975. Reference 3 is an interim progress report summarizing the experimental findings of the Phase I efforts.

The following technical report encompasses the Phase I and Phase II efforts of the testing and analytical studies group. It should be noted that the information presented herein supersedes the data of Reference 3.

TEST PROGRAM

OBJECTIVE

The objective of the test program was to collect the necessary data to establish the fragmentation characteristics of 155-mm projectiles when simultaneously detonated in typical storage configurations. The fragmentation data included polar and azimuthal spatial reference for fragment weights, numbers, velocities, and presented areas.

APPROACH

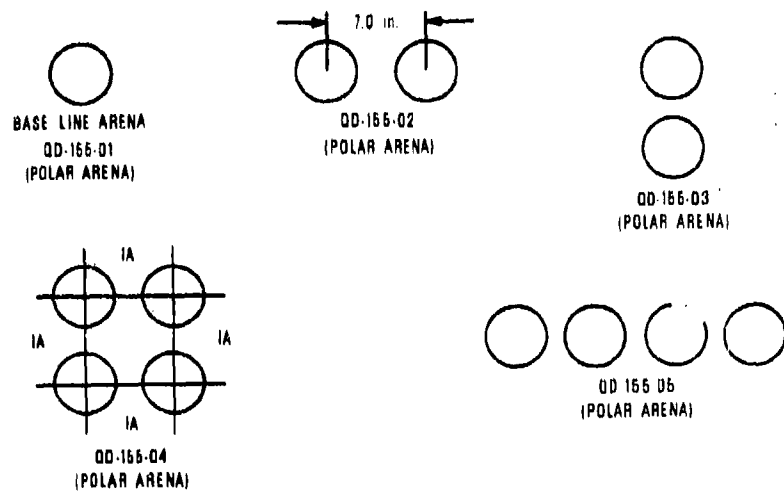
The data required to characterize the simultaneous detonation of projectiles in a cluster was accumulated by conducting a series of fragmentation arena tests. All of the arena tests in the series were based on two specific arena configurations.

The first type of arena was designed to determine the fragment weights, numbers, and velocities as a function of polar angle measured in the horizontal plane from the direction of the noses of the projectiles in a cluster with their axes horizontal. The arena will be referred to as a polar angle arena for discussions in this report. The second type of arena was designed to collect the same type of fragment data as the polar angle arena except as a function of azimuthal angle measured in the horizontal plane from one of the planes of symmetry of a cluster of projectiles with their axes vertical. This second type of arena will be referred to as an azimuthal angle arena in this report.

The test series began with three repeated single round detonations in one polar angle arena. The data from these tests were compared with existing literature to ensure the adequacy of the testing and data collection procedures. These data were used as baseline data for the comparison of data from the simultaneous detonation of projectiles in a cluster. The test series continued with the simultaneous detonation of projectiles in increasingly larger clusters in the polar or azimuthal angle arenas. During the conduct of the test program, it became necessary to deviate from the test plan. The deviations have been explained in this report where applicable.

Projectile Cluster Configurations

The single round and the eight multiple round projectile configurations shown in Figures 1 and 2 were used to collect the fragmentation data presented in this report. Each cluster configuration was assigned a specific identification number and tested in either a polar or azimuthal angle arena. The clusters were tested in the order presented in Figures 1 and 2, from left to right, then top to bottom. Each configuration was a subset of the standard eight round shipping configuration with



- NOTES:
1. CIRCLES DENOTE PROJECTILES ORIENTED HORIZONTALLY
 2. IA DENOTES INTERACTION AREA

Figure 1. Projectile Cluster Configurations

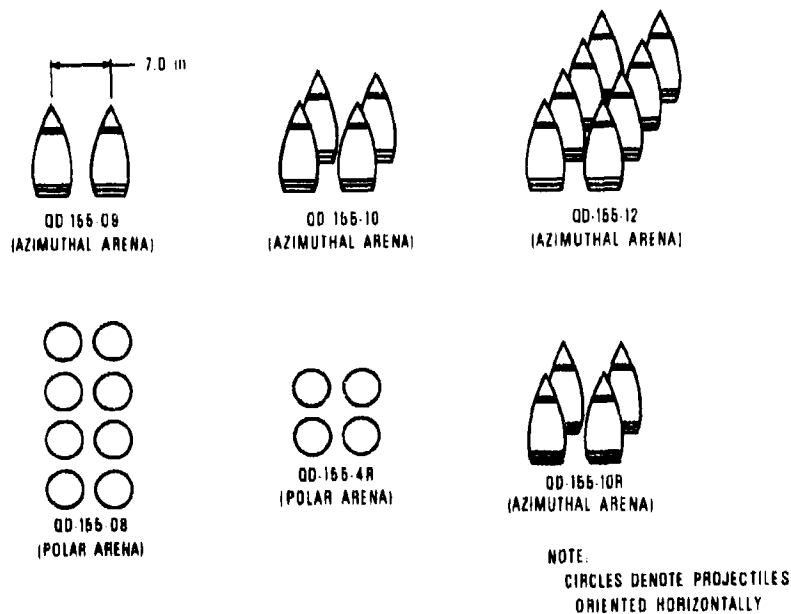


Figure 2. Projectile Cluster Configurations

projectile spacing maintained at seven inches center-to-center. Each cluster of two or more projectiles in Figures 1 and 2 has two planes of symmetry. With this symmetry, it was possible to collect fragments on one side of the arena and measure the corresponding velocities on the other in the same test. The space between any two adjacent projectiles is defined as the interaction area. An example of the geometric boundaries designated as the interaction areas for configuration QD-155-04 is shown in Figure 1.

Fragmentation Test Methods

The test methods utilized throughout the test series reflect the basic test designs and definitions presented in Reference 4. Each arena test was identified with a number that corresponded to the projectile cluster configurations in Figures 1 and 2. Unless otherwise specified, each arena test consisted of three firings of identical projectile clusters or of a single projectile, that were detonated in the same arena configuration. All projectiles in a cluster were primed and detonated simultaneously.

Simultaneity was achieved in the multiple detonation tests by using equal lengths of Du Pont 49-grain per foot detonating cord. The detonating cord was fashioned into the harness initiation device shown in Figure 3. Each leg of the harness was crimped with a DuPont P-3, detonator and positioned in a modified U.S. Army M564 PD nose fuze. The entire arrangement was assembled on the projectile cluster and remotely initiated by detonating a Hercules Vibrodet HC-15 blasting cap at the harness junction. This initiation device was not utilized in the earlier stages of the test series. The initiation system that was used during the earlier tests consisted of Hercules Engineer's Special blasting caps assembled in M564 nose fuzes and wired in series. This series initiation system proved to be inadequate in achieving a simultaneous detonation due to the

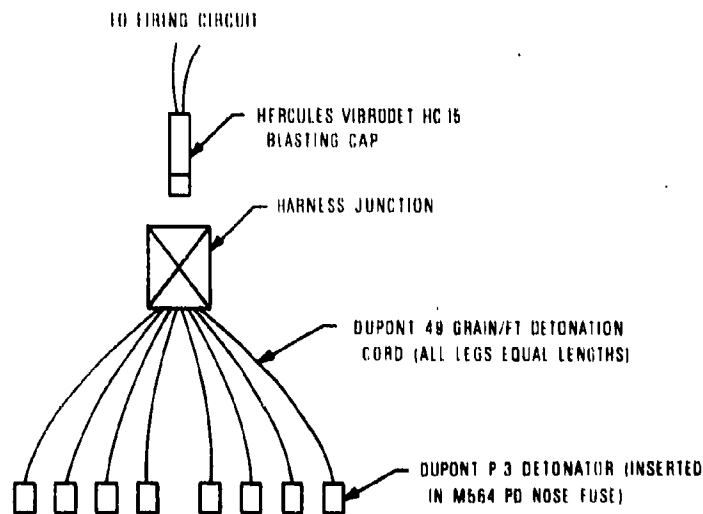


Figure 3. Harness Initiation Device for Full Pallet Configuration

inherent time delays (milliseconds) between the functioning of the blasting caps. The harness shown in Figure 3 was used for arena test QD-155-12 and all subsequent arena tests.

The polar and azimuthal angle arena configurations were designed to obtain fragment weights, numbers, presented areas and velocities for specific spatial reference zones. Fragment weight and number data were obtained by collecting the ejected fragments in a fiber-board building material. The fiber-board is marketed under the trade name Celotex. The Celotex was configured in bundles, 4 x 4 x 8 ft, and positioned in the test arena according to fragment collection zone requirements. A surveyor's transit was used to identify the fragment collection zones within 0.5° tolerances. The fragments were extracted from the Celotex after the test, cleaned, weighed and documented according to spatial zones.

The presented areas of the fragments were measured with either a planimeter or an Electro-Optic Icosahedron gage (Reference 5) depending upon fragment size. The fragment velocity data were recorded with high-speed motion picture cameras equipped with millisecond timing generators. The cameras were used to record the detonation of the projectiles and fragment scintillations on 22-gauge mild steel witness panels marked according to the spatial zones under investigation. Figure 4 is a photograph of a typical arena with the steel witness panels and Celotex marked in polar zones.

BASELINE ARENA TEST

The first arena test conducted in the test program was the baseline arena test, ID Number QD-155-01. The test was designed to collect fragment characterization data from the detonation of a single round. This test also provided original fragment weight and number data not available elsewhere and made available the actual fragments and photographic velocity records for analysis. The data from this arena test were collected under conditions that were similar to those used to collect all test data for the program.



Figure 4. Typical Fragmentation Arena With Steel Witness Panels and Celotex Marked in Polar Zones

The baseline arena test was conducted 10 and 11 July 1975. Three 155-mm projectiles were individually detonated in a polar angle arena configured as shown in Figure 5. Each projectile was detonated with a M564 nose fuze modified to accept a Hercules Engineer's Special, No. 12 blasting cap. Fragments were collected and velocity data were recorded in 5° increments over polar zones 0° to 180°. The fragment weights, numbers, and velocities are presented in Appendix A. A plot of the average fragment velocities versus polar zone for the three arena firings is presented in Figure 6.

MULTIPLE PROJECTILE ARENA TESTS

This section addresses the simultaneous detonation of projectiles in a cluster in polar and azimuthal angle arenas. The arena tests are listed by test identification numbers and presented in the order that the tests were conducted. An identification number represents three repeated firings of a particular projectile cluster in the same arena configuration unless otherwise specified.

Test QD-155-02

This test was conducted 11, 12 and 13 August 1975. Two 155-mm projectiles oriented horizontally, side by side, with the projectile centerlines parallel and seven inches apart were detonated simultaneously in a polar angle arena configured the same as the baseline arena shown in Figure 5. The purpose of detonating the side by side cluster was to investigate whether or not neighboring projectiles affect the fragment velocity and weight-number data. The cluster of projectiles was detonated with two modified M564 nose fuzes assembled with Hercules Engineer's Special blasting caps wired in series. Fragments were collected 18° azimuthally in 5° polar zones from 0° to 180°. Velocities were recorded 27° azimuthally in 5° polar increments from 0° to 180°.

Post test inspection of all three firings revealed no appreciable increase in fragment concentrations as compared with the baseline arena. However, several one- and two-pound fragments were found on the ground within the immediate arena area indicating a possible change in the fragment weight distribution. The fragment weights, numbers, and velocities are presented in Appendix A. A close inspection of the velocity data indicates that the fragments being ejected from the areas outside of the interaction areas (Figure 1) have basically the same shape velocity curve as a single round (Figure 6). A plot of the average velocities versus polar zone for the three arena firings is presented in Figure 7.

Test QD-155-03

This test was a polar angle arena test conducted on 10, 12, and 13 September 1975. The test consisted of the simultaneous detonation of two 155-mm projectiles in a horizontal orientation. The projectiles were stacked on top of each other and positioned as shown in the polar arena layout of Figure 8. The objective of this arena test was to determine the fragmentation characteristics for the projectile interaction area over a 180° polar sector. The projectiles were detonated utilizing the same type of nose fuze and blasting cap assembly used in arena QD-155-02. Likewise, fragments were collected and velocities were recorded in the same spatial zones as for arena QD-155-02.

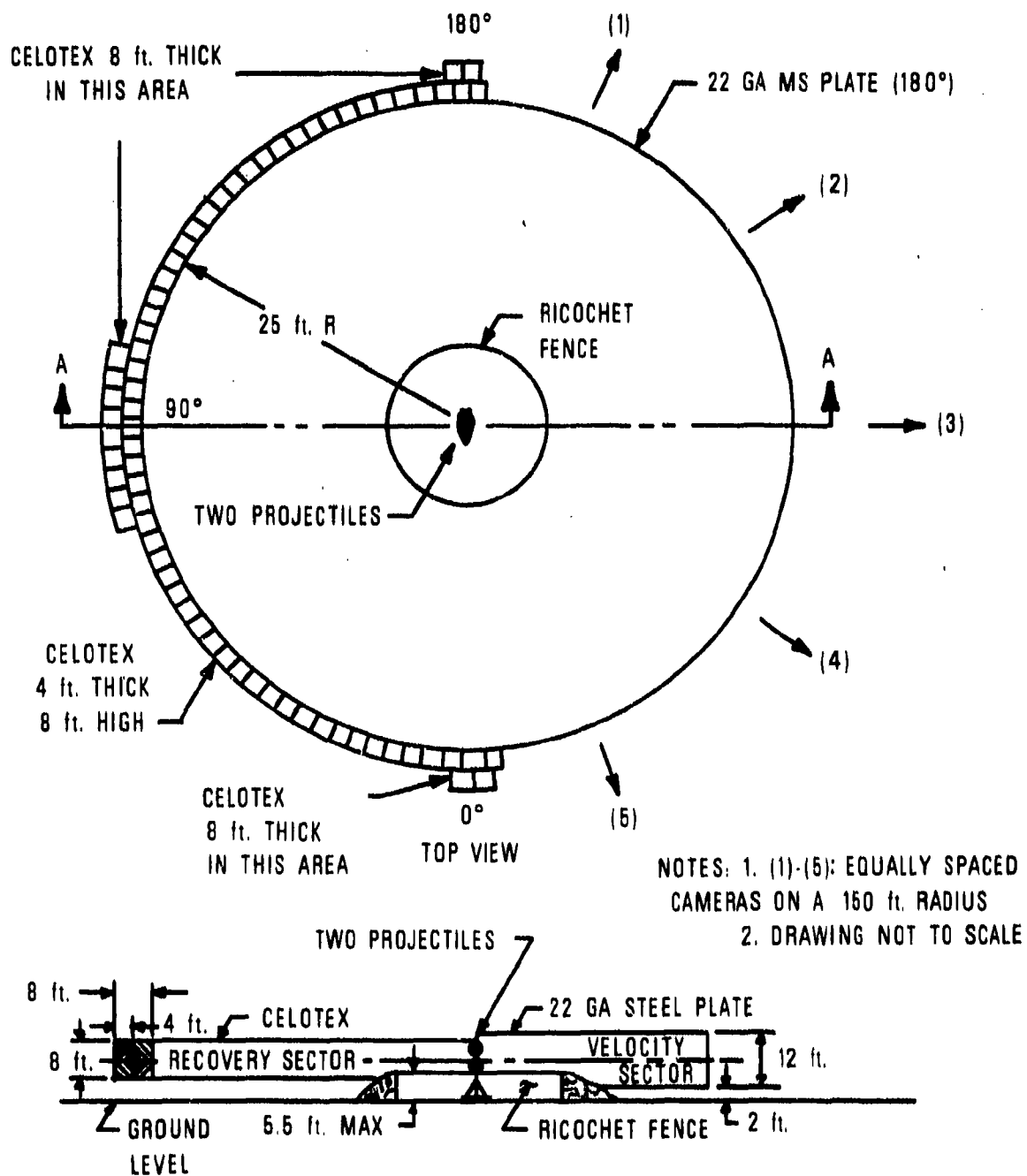


Figure 5. Polar Angle Arena Layout for Test No. QD-155-01

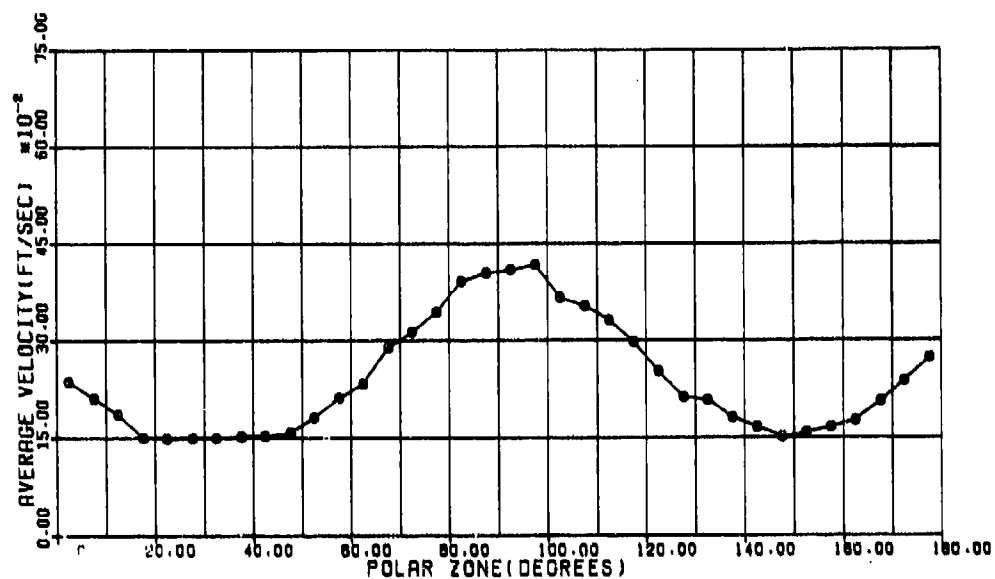


Figure 6. Average Fragment Velocities of all Firings
for Test No. QD-155-01

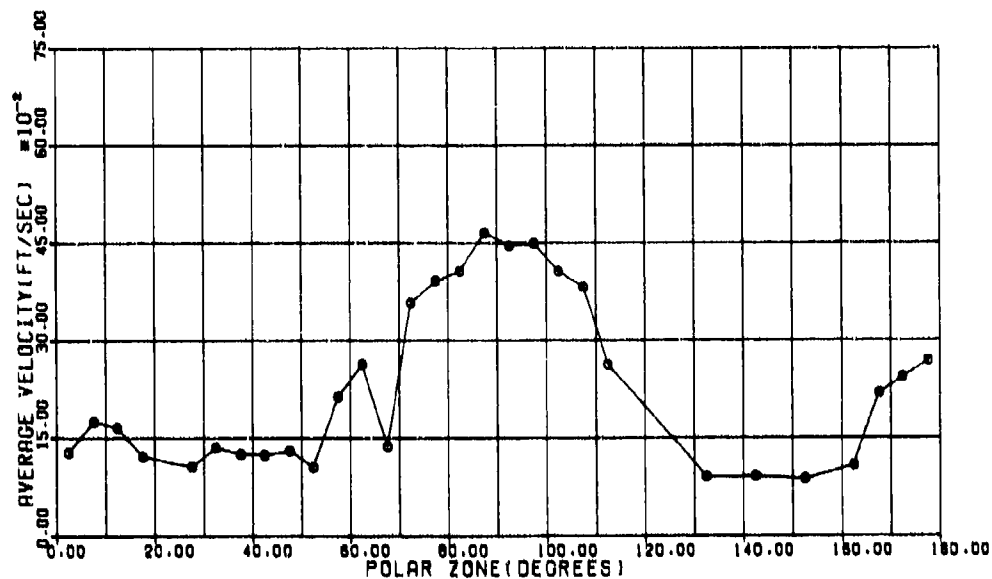
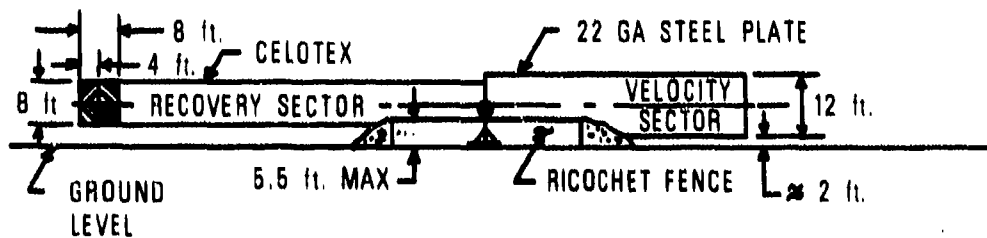


Figure 7. Average Fragment Velocities of all Firings
for Test No. QD-155-02



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Post test inspections revealed that an increase in the fragment density had occurred when the data was compared with the data from the baseline arena test. The increase in fragment density was evenly distributed throughout the azimuthal sector. The fragmentation data are presented in Appendix A. The fragment velocities did not increase in the interaction area. It was suspected that the neighboring projectiles would provide an additive effect in the fragment velocities. Instead, the shape of the velocity curve is similar in magnitude to the baseline arena. Further investigations conducted with information from later arena tests in this test sequence revealed that these cluster detonations were not simultaneous. Even though the cluster detonations were found to be non-simultaneous, the velocity data were plotted as an average of the three firings to show the predominant shape of the curve. The fragment velocity plot for test QD-155-03 is presented in Figure 9.

Test QD-155-04

This test was a polar angle arena test conducted on 23, 28, and 29 October 1975. The test consisted of the simultaneous detonation of four projectiles in a horizontal orientation. Two of the projectiles were stacked on top of the other two projectiles as shown in Figure 1. The projectile cluster was positioned in the polar angle arena layout shown in Figure 10 and detonated with the same blasting cap arrangement described in the earlier arena tests. The objective of this test was to investigate the effect of the back-to-back projectile interaction areas on the fragment characteristics. The arena was configured the same as the previously mentioned arenas except for the size of azimuthal recovery zone. The radius of the Celotex was changed from 25 ft to 30 ft to reduce blast damages. (An increase in the explosive weight requires the Celotex to be moved radially outward proportional to the cube root of the explosive weight). This change resulted in a 15° azimuthal recovery zone. All of the other spatial references remained the same.

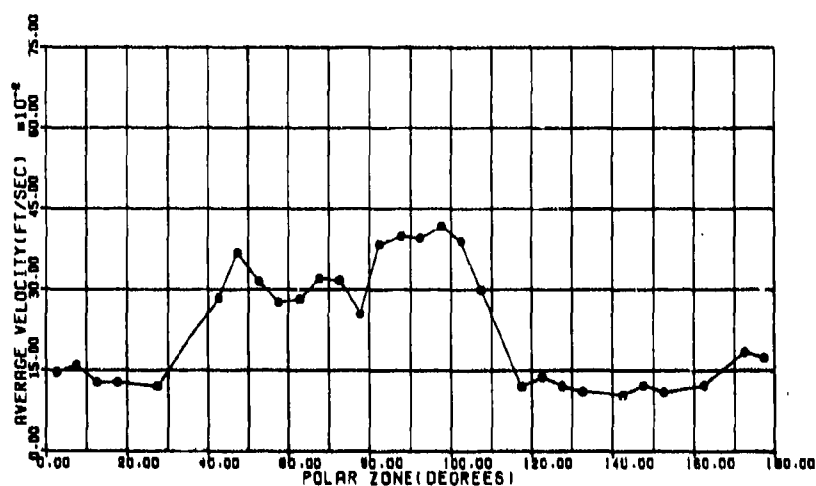


Figure 9. Average Fragment Velocities of all Firings
for Test No. QD-155-03

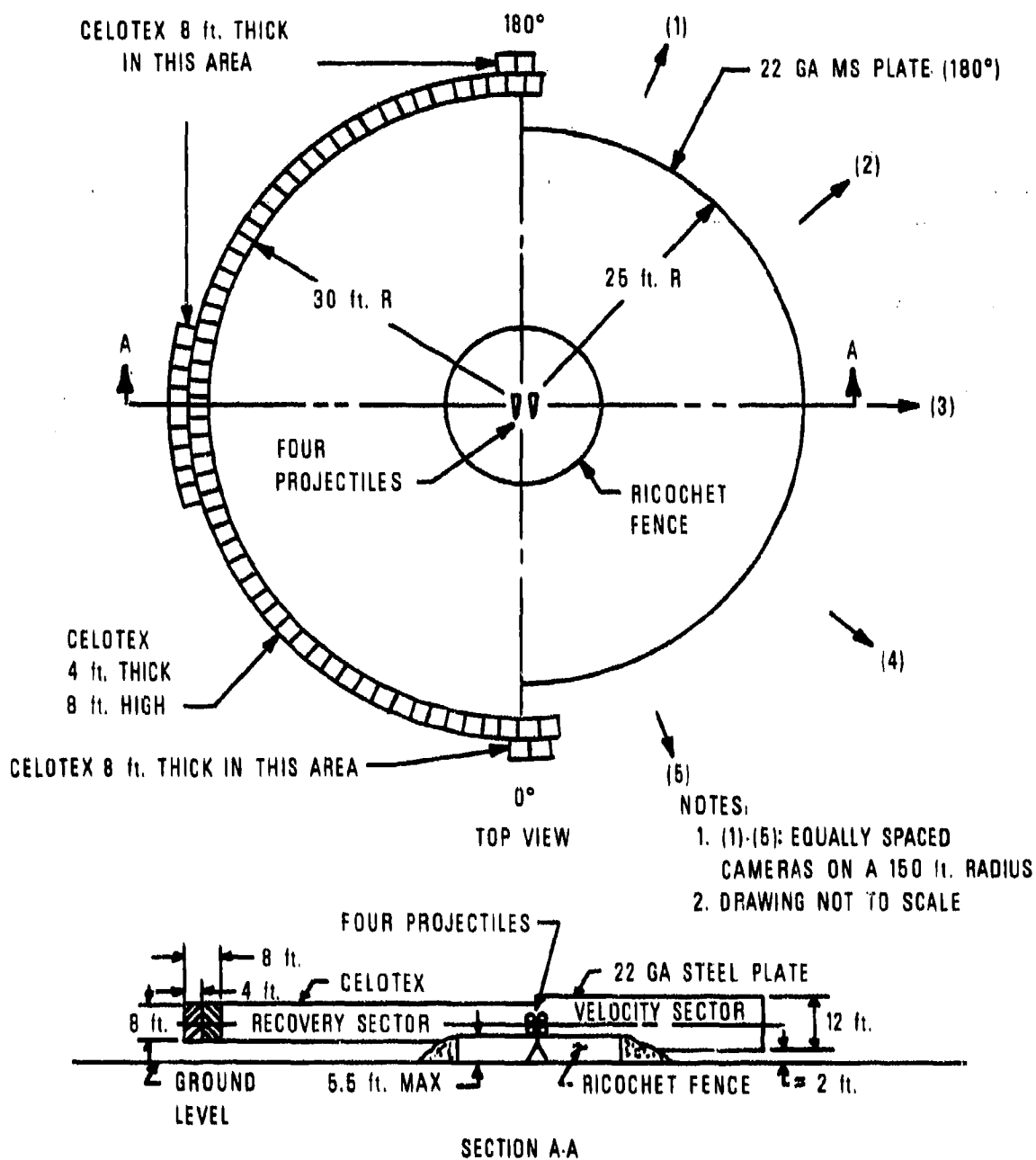


Figure 10. Polar Angle Arena Layout for Test No. QD-155-04

Inspections of the velocity panels after the test revealed evidence of very large fragments. One fragment hole in the 95° to 100° polar zone was 10-in. long and approximately 4-in. wide. One fragment approximately 12-in. long and 3-in. wide was found just outside the arena circumference. Severe damage to the Celotex bundles resulted in the 80° to 95° polar zones. Also, fragment densities and velocities were extremely high in the 60° to 110° polar zones with noticeable shifts in the azimuthal direction. The azimuthal shift in velocity indicates the detonations were not simultaneous. Fragment weights, numbers and velocities are presented in Appendix A. A plot of the average fragment velocities for the three firings versus polar zone is presented in Figure 11.

Test QD-155-05

This test was a polar angle arena test conducted on 26 November, 2, and 3 December 1975. The test consisted of four projectiles positioned side by side as shown in Figure 1 and detonated in the polar angle arena configured as shown in Figure 12. The projectiles were detonated with the same type of modified M564 fuze and blasting cap assembly as used in the previous arena tests. The objective of this arena test was to gain more information about the additive effects of the fragmentation phenomena caused by neighboring projectiles. Fragments were collected 11° azimuthally in 5° polar zones from 0° to 180°. Velocities were recorded 27° azimuthally in 5° polar increments from 0° to 180°.

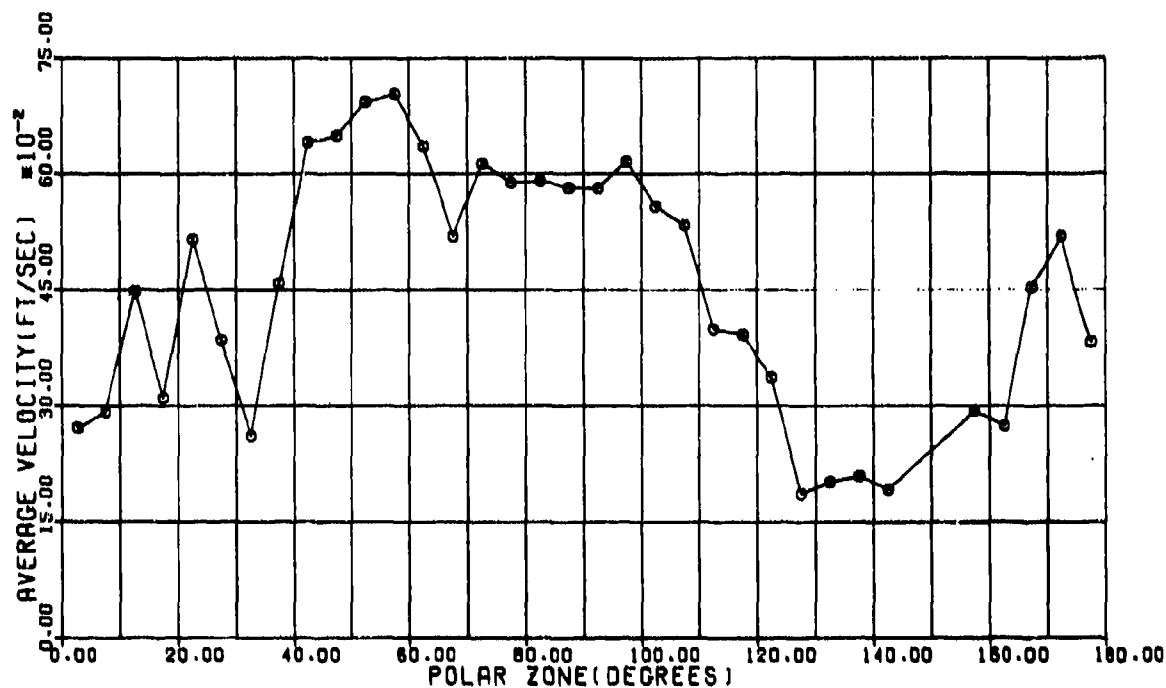


Figure 11. Average Photographic Velocities of all Firings
for Test No. QD-155-04

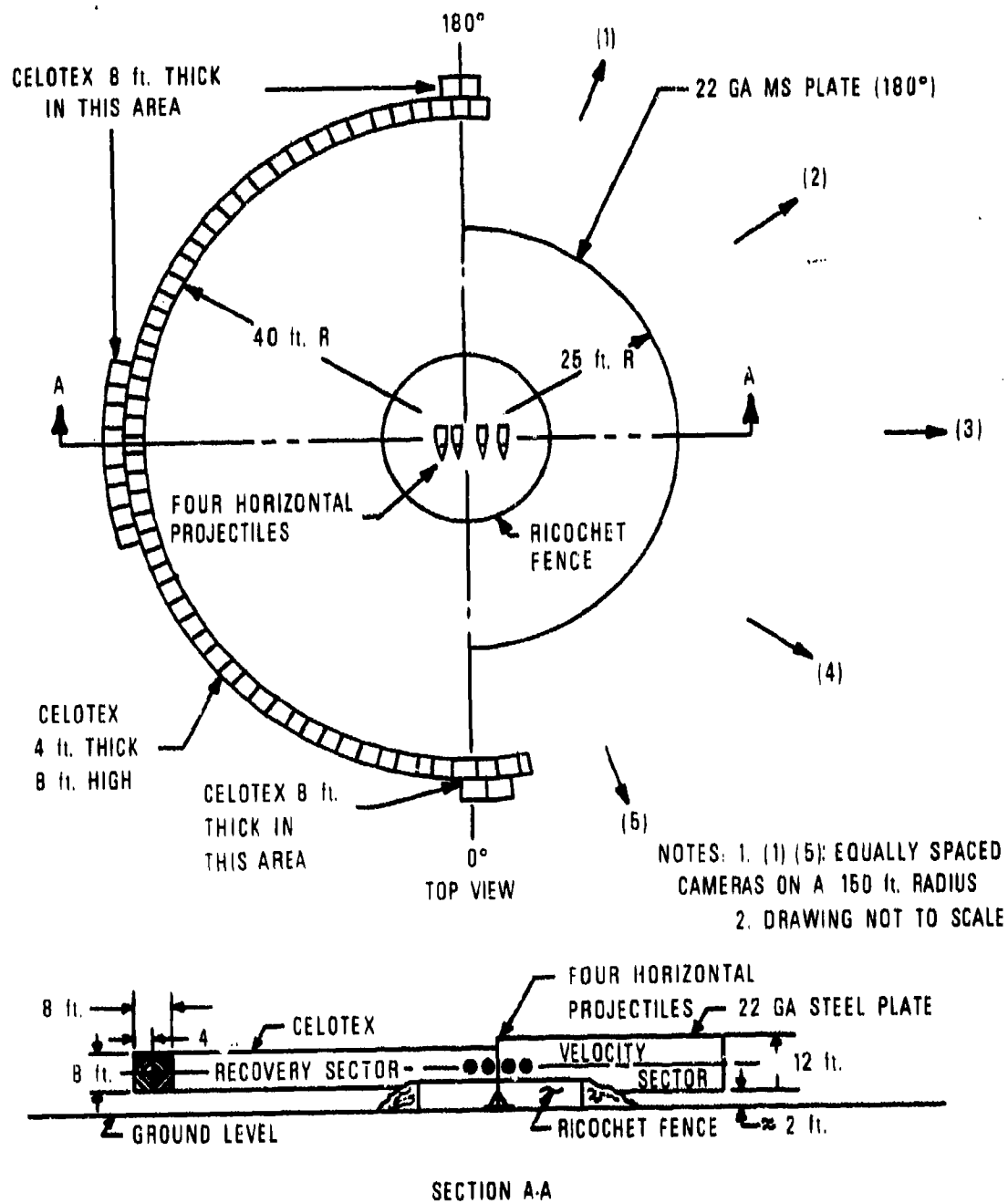


Figure 12. Polar Angle Arena Layout for Test No. QD-155-05

Post test inspection of the three firings revealed that the fragment hits in the witness panels and Celotex were similar to those in the baseline arena test QD-155-01. The fragment collection data and velocity information are presented in Appendix A. The fragment velocity curves were also similar to the baseline arena. A plot of the average fragment velocities for the three arena firings of QD-155-05 is shown in Figure 13.

Test QD-155-09

This azimuthal angle arena test was the first modification to the typical fragmentation arena shown in Figure 4. Data analysis for test QD-155-04 revealed an increase in fragment velocities as much as double the velocities in similar zones of the baseline test. Azimuthal shifts of the fragment hits on the witness panels were also evident. In general, the projectile interaction areas were causing large fragment concentrations or fragment jets at high velocities in varying azimuthal directions. Arena test QD-155-09 was conducted to investigate the fragmentation phenomena in the interaction areas. The test was conducted 20, 21, and 22 April 1976. Two projectiles were positioned vertically with the axial centerlines seven inches apart and detonated in an azimuthal angle arena configured as shown in Figure 14. Projectile fragments were collected in 5° polar and 10° azimuthal zones bounded by 85° to 100° polar and 0° to 135° azimuthal angles. Fragment velocity data were recorded photographically for 5° polar and 10° azimuthal zones bounded by 80° to 105° polar and 180° to 360° azimuthal angles as shown in Figure 14.

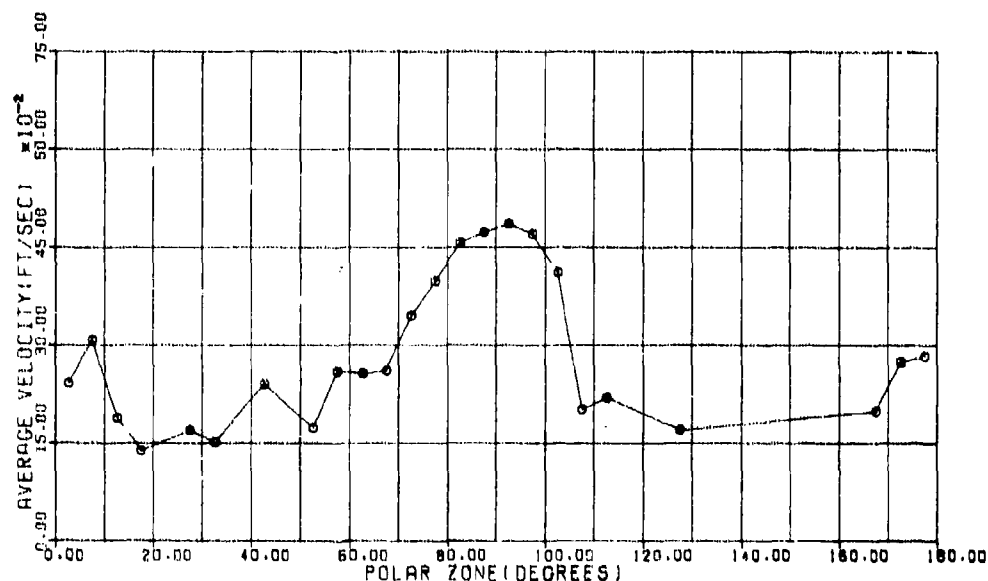


Figure 13. Average Fragment Velocities of all Firings
for Test No. QD-155-05

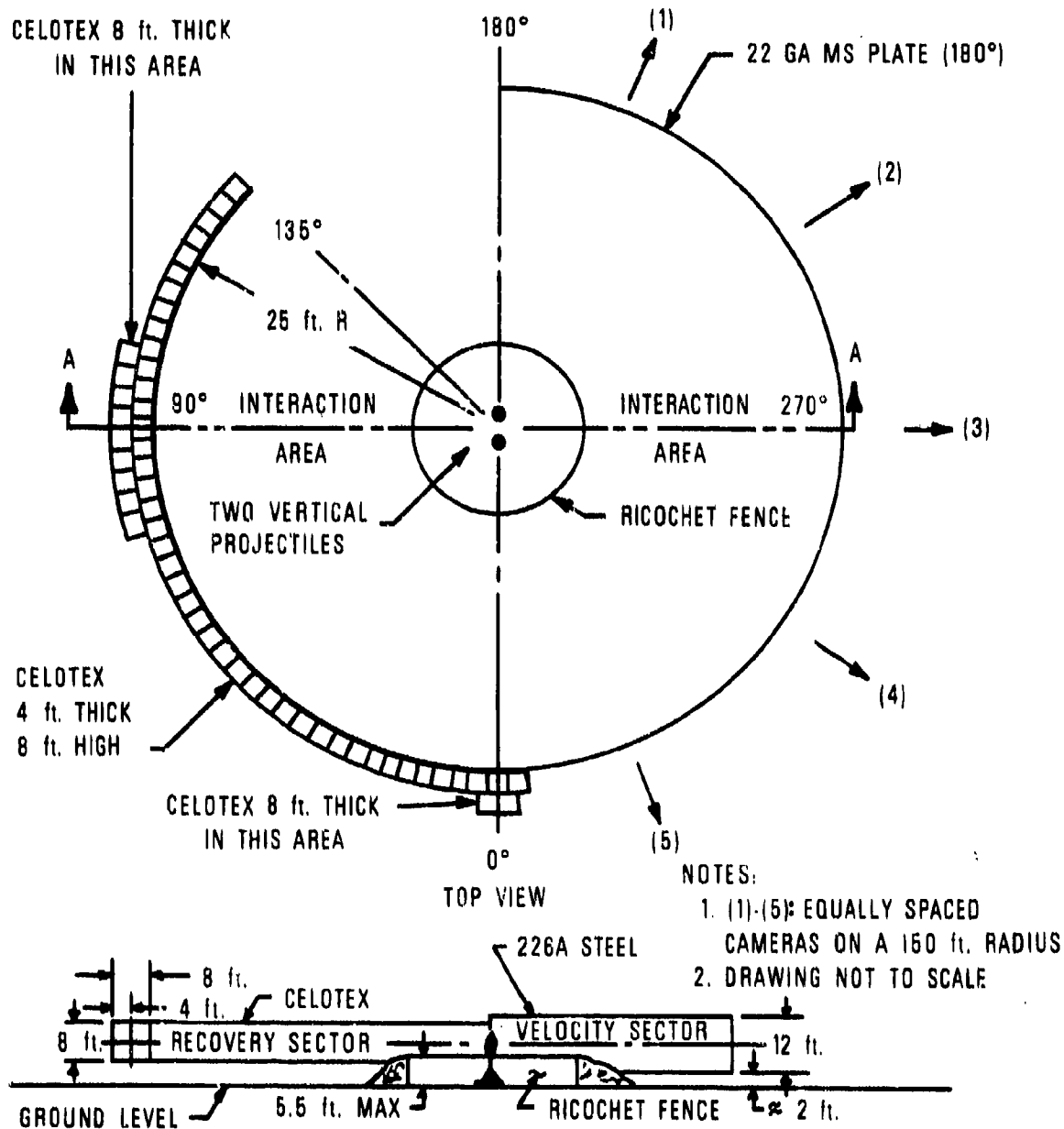


Figure 14. Azimuthal Angle Arena Layout for Test No. QD-155-09

Post test inspections of the Celotex and velocity panels revealed that a fragment jet had occurred at the projectile interaction area. Photographic inspections also confirmed the azimuthal shifts in the distribution of the fragments and the increase in velocities similar to the ones seen in test QD-155-04. The fragmentation data are presented in Appendix A. Figures 15, 16 and 17 are fragment velocity plots from the three arena firings depicting the velocity variations and azimuthal shifts of the fragment jets in the polar zone 95-100°.

Test QD-155-10

This azimuthal angle arena test was conducted 21, 25 and 27 May 1976. Four projectiles were positioned vertically as shown in Figure 2 and detonated in the arena configured as shown in Figure 18. The test was designed to investigate the additive effect of back-to-back projectile interaction areas on the fragment distributions, and to investigate the azimuthal shifts in fragment distributions which were present in test QD-155-04 and test QD-155-09. Fragments were collected in 5° polar and 10° azimuthal zones bounded by 85° to 100° polar and 20° to 140° azimuthal angles. Fragment velocity data were recorded photographically for 5° polar and 10° azimuthal zones bounded by 80° to 105° polar and 200° to 20° azimuthal angles as shown in Figure 18.

Inspections of the witness panels and Celotex after the first detonation of four projectiles revealed that high density fragment jets were occurring similar to the fragment jets observed in test QD-155-09. Figure 19 is a photograph taken from a high speed motion picture film showing two of the fragment jets. The jets did not occur, as expected, at the 270° and 360° interaction areas as shown in Figure 18. The jets were shifted toward each other and occurred at the approximate azimuthal angles 280° and 330°. It was suspected that small time delays (milliseconds) between projectile detonations were responsible for the directional shifts. Due to the shifting jet phenomena, additional Celotex was positioned as shown in Figure 20 at the 180° interaction area for the remaining two detonations. The Celotex was replaced for each firing so that the jet fragments from individual firings could be analyzed. The jet fragments from the 180° interaction area were collected on the second firing but completely missed the Celotex on the third firing. There were also several fragments weighing approximately one pound found on the ground within the arena circumference after the three detonations. The fragmentation data are presented in Appendix A. Figures 21 and 22 are fragment velocity plots which show the azimuthal shifts in direction and magnitude for the first and second arena firings of test QD-155-10.

Test QD-155-12

This was the first test in the series in which a full pallet of projectiles were detonated. The eight projectiles were positioned vertically as shown in Figure 2 and detonated on 8 and 19 July 1976 in an azimuthal angle arena configured as shown in Figure 23. Fragments were collected in 5° polar and 10° azimuthal zones bounded by 90° to 100° polar and 340° to 140° azimuthal angles. Fragment velocity data were recorded in 5° polar and 10° azimuthal zones bounded by 80° to 105° polar and 160° to 340° azimuthal angles as shown in Figure 23.

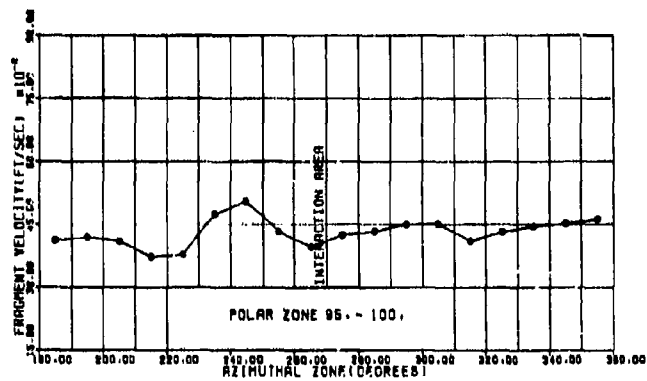


Figure 15. Fragment Velocities from Firing No. 1
for Test No. OD-155-09

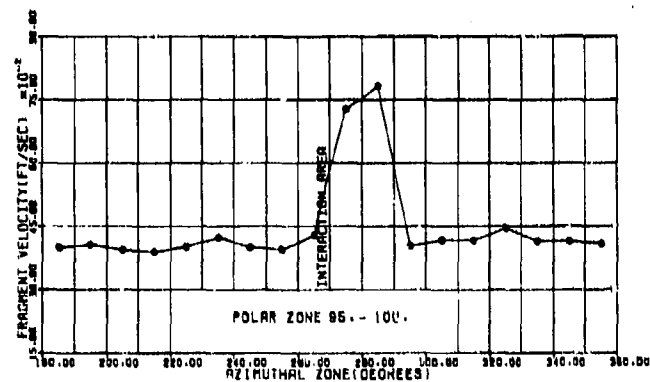


Figure 16. Fragment Velocities from Firing No. 2
for Test No. QD-155-09

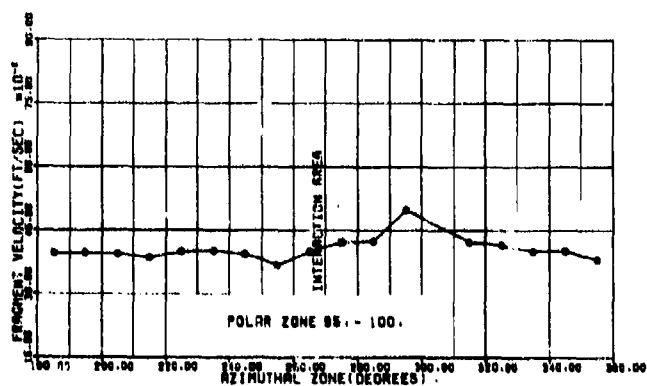


Figure 17. Fragment Velocities from Firing No. 3
for Test No. QD-155-09





Figure 19. Fragment Jet Scintillations for Test QD-155-10 (Firing No. 1)

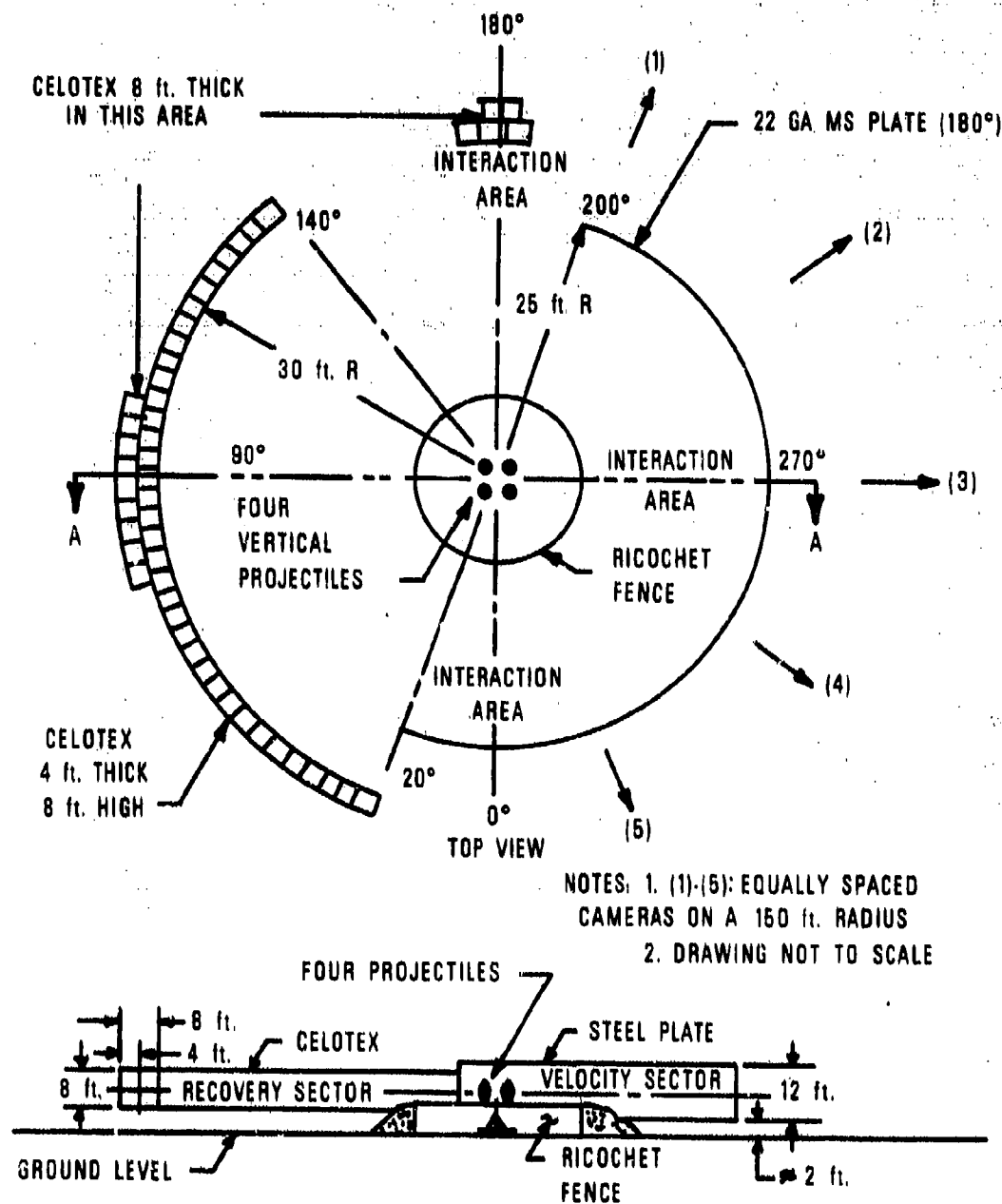


Figure 20. Azimuthal Arena Layout for Test No. QD-155-10
(Firings No. 2 and 3)

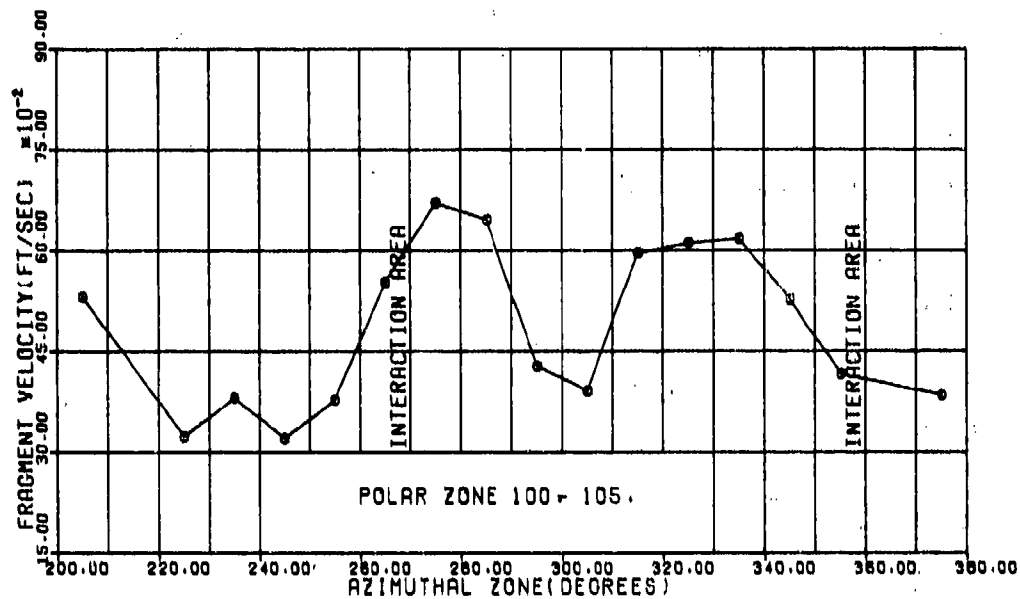


Figure 21. Fragment Velocities from Firing No. 1
for Test No. QD-155-10

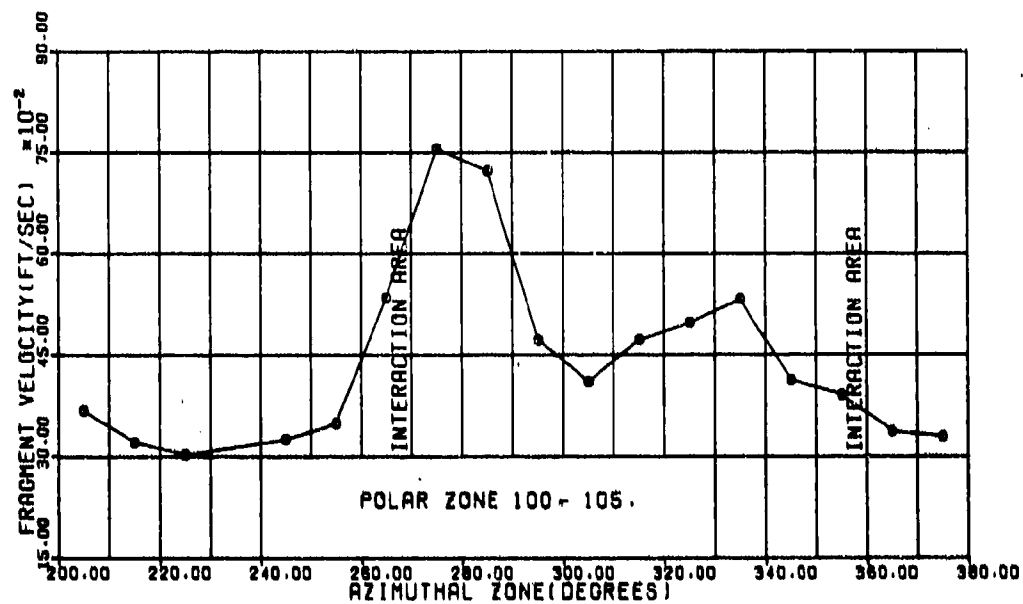


Figure 22. Fragment Velocities from Firing No. 2
for Test No. QD-155-10

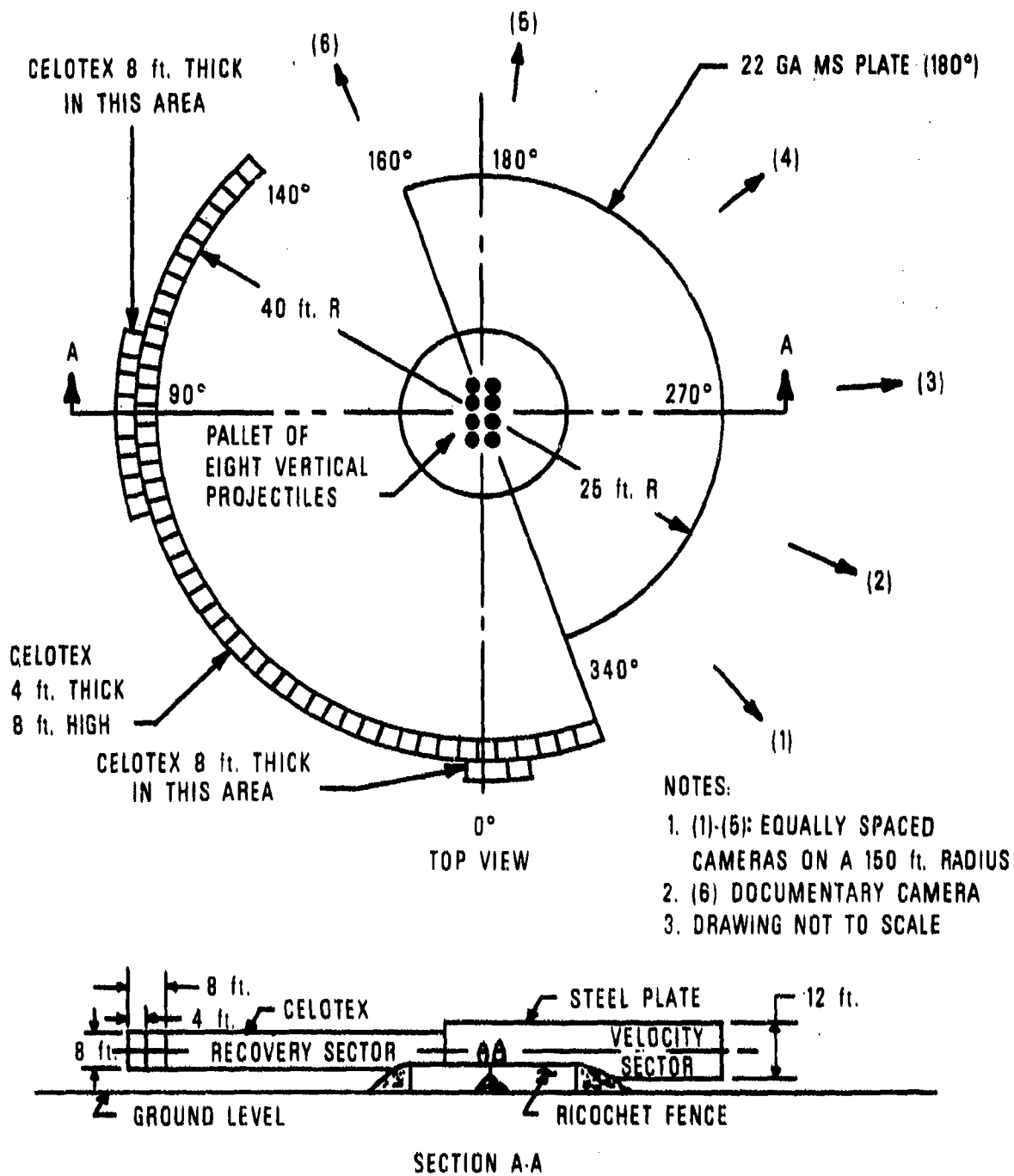


Figure 23. Azimuthal Angle Arena Layout for Test No. QD-155-12

The data from test QD-155-09 and test QD-155-10 indicated that there were deficiencies in the system used to initiate the detonation (blasting caps wired in series). There was sufficient time delay between the functioning of the blasting caps to cause an appreciable shift in the direction of the high velocity fragment jets. The initiation harness shown in Figure 3 was designed and tested prior to the start of this test. Electronic instrumentation was used to measure the time delays inherent to the device. Test results indicated that the time delays (seven microseconds between the initiation of the first and last P-3 detonators) were negligible and that the harness would provide adequate simultaneity.

An inspection following the detonation of the first pallet of projectiles revealed that simultaneity had been achieved. Well defined fragment concentrations occurred on the witness panels and Celotex recovery packs at 0°, 90°, and 180° azimuthal angles. Figure 24 is a photograph taken from a high speed motion picture film depicting the development of the fragment jet at the 180° azimuthal angle. Due to the large numbers of fragments from the four projectile interaction areas (Figure 23), a complete change of Celotex was required prior to the detonation of the second pallet of projectiles. There were many large and chunky fragments recovered from the ground within the arena circumference. A selection of these fragments is presented in Figure 25. A third pallet of projectiles was not detonated because the data from the first two firings were completely repeatable and it was felt that enough fragmentation data had been accumulated to characterize the pallet configuration. The fragmentation data are presented in Appendix A. A plot for each polar zone of the average fragment velocities versus azimuthal zone for both arena firings is presented in Figures 26 through 30. An inspection of each plot shows a definite increase in the fragment jet velocity as the polar angle increases. This is due to the fact that the spacing between the ogive areas is larger than in the rotating band and boattail areas. It is also shown by the plots that the fragment velocities outside the interaction areas compare with fragment velocities of similar zones from the baseline arena test.

Test QD-155-08

This test consisted of the detonation of a full pallet of projectiles. The cluster configuration was two vertical stacks of four projectiles oriented horizontally with their centerlines seven inches apart as shown in Figure 2. The projectiles were detonated in a polar angle arena configured as shown in Figure 31. The first firing was conducted 26 August 1976. The harness initiation device was used to simultaneously detonate the projectiles. The purpose of the test was to characterize the fragment jets and to investigate the back-to-back effect of the three projectile interaction areas through a 180° polar sector. Fragments were collected 11° azimuthally in 5° polar zones from 0° to 180°. The velocity data were recorded 27° azimuthally through the same polar zones.

Inspections after the first firing revealed similar results to those of test QD-155-12. Fragment hits on the velocity panels and Celotex indicated that one fragment jet had formed from the three

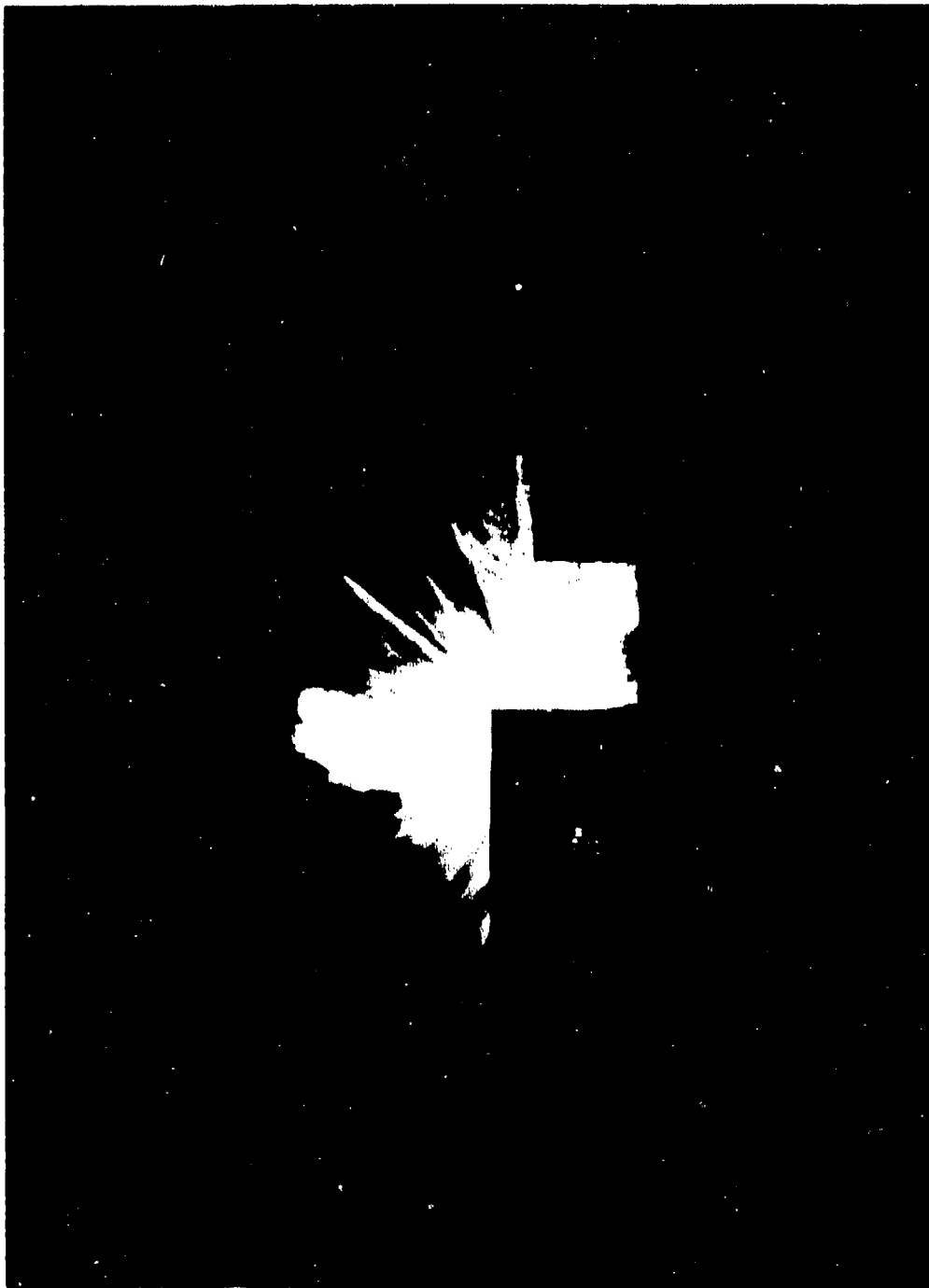


Figure 24. Formation of High Velocity Fragment Jet
at 180° Azimuthal Angle for Test QD-155-12

TIME IN 2103

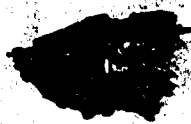
TEST ID OD-155-12

P.H.D. NO. 0814-3-77

ARENA FIRING NO. 1



3.31 K_g
(7.39 LBS)



2.67 K_g
(5.89 LBS)



2.44 K_g
(5.38 LBS)



2.40 K_g
(5.29 LBS)



2.27 K_g
(5.01 LBS)



2.06 K_g
(4.54 LBS)



2.00 K_g
(4.42 LBS)



2.00 K_g
(4.42 LBS)



0.91 K_g
(2.01 LBS)



0.79 K_g
(1.75 LBS)

ARENA FIRING NO. 2



2.80 K_g
(6.18 LBS)



2.59 K_g
(5.71 LBS)



2.37 K_g
(5.23 LBS)



2.36 K_g
(5.20 LBS)



2.33 K_g
(5.15 LBS)



1.85 K_g
(4.07 LBS)



0.94 K_g
(2.08 LBS)



0.77 K_g
(1.69 LBS)



0.60 K_g
(1.32 LBS)



0.54 K_g
(1.18 LBS)



Figure 25. Fragments Collected From the Ground
for Test QD-155-12

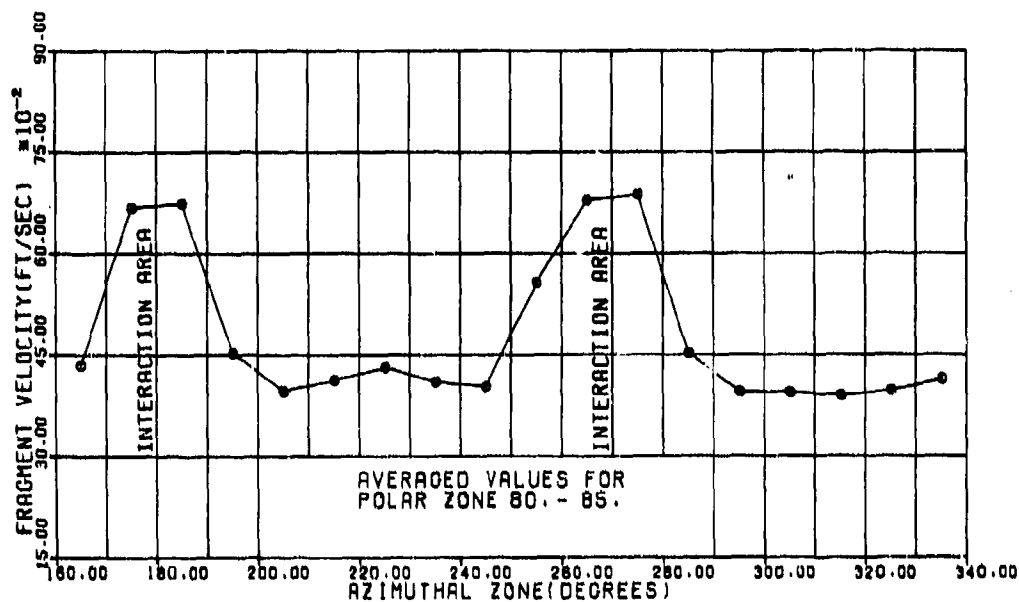


Figure 26. Average Fragment Velocities of all Firings
for Test No. QD-155-12 (Polar Zone 80°-85°)

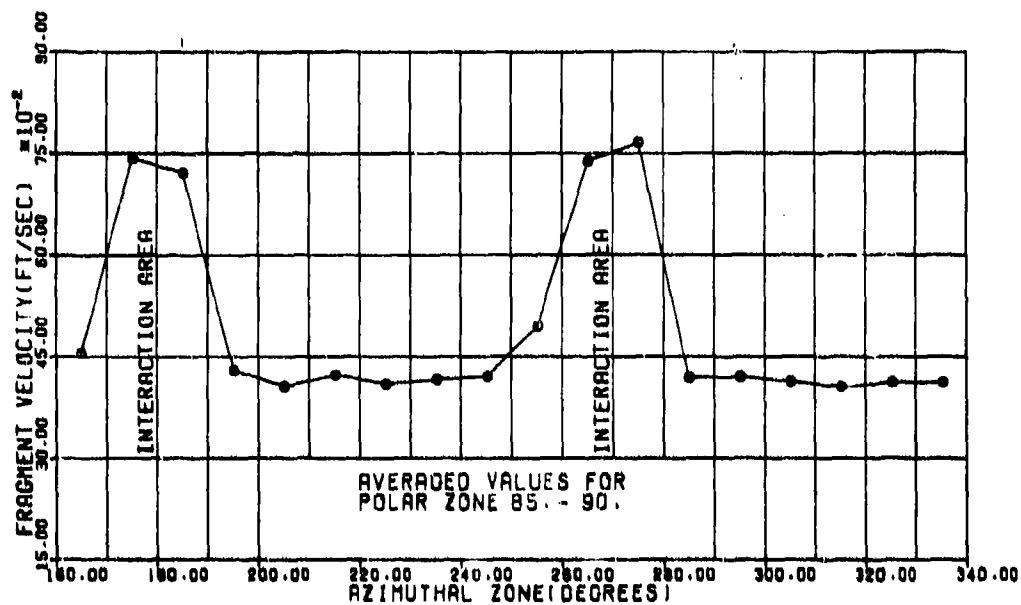


Figure 27. Average Fragment Velocities of all Firings
for Test No. QD-155-12 (Polar Zone 85°-90°)

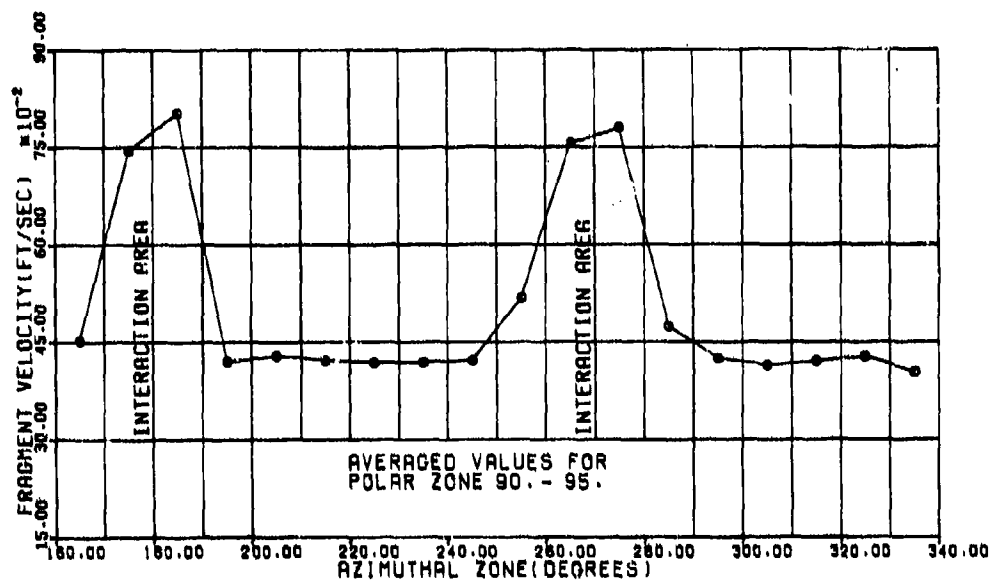


Figure 28. Average Fragment Velocities of all Firings
for Test No. QD-155-12 (Polar Zone 90°-95°)

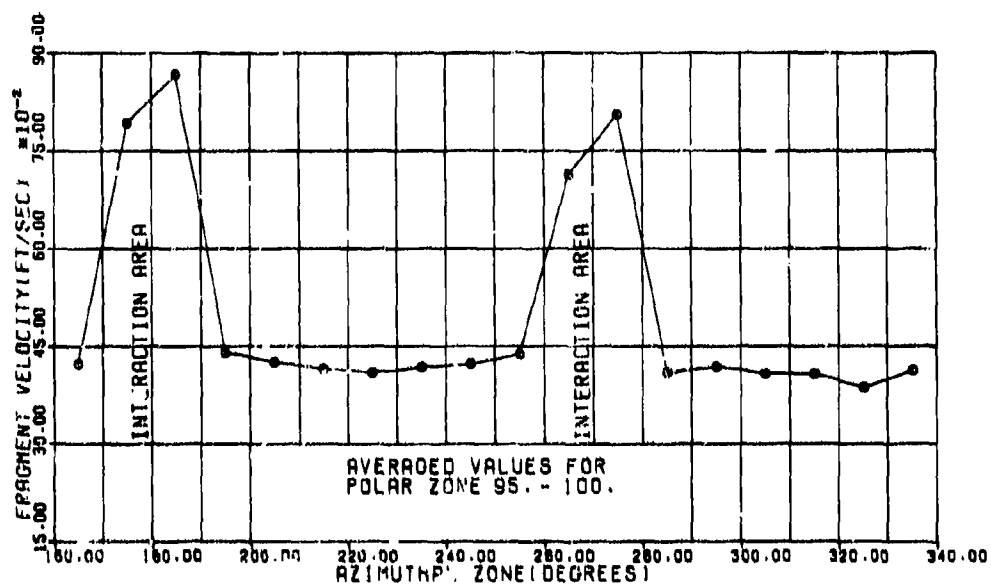


Figure 29. Average Fragment Velocities of all Firings
for Test No. QD-155-12 (Polar Zone 95°-100°)

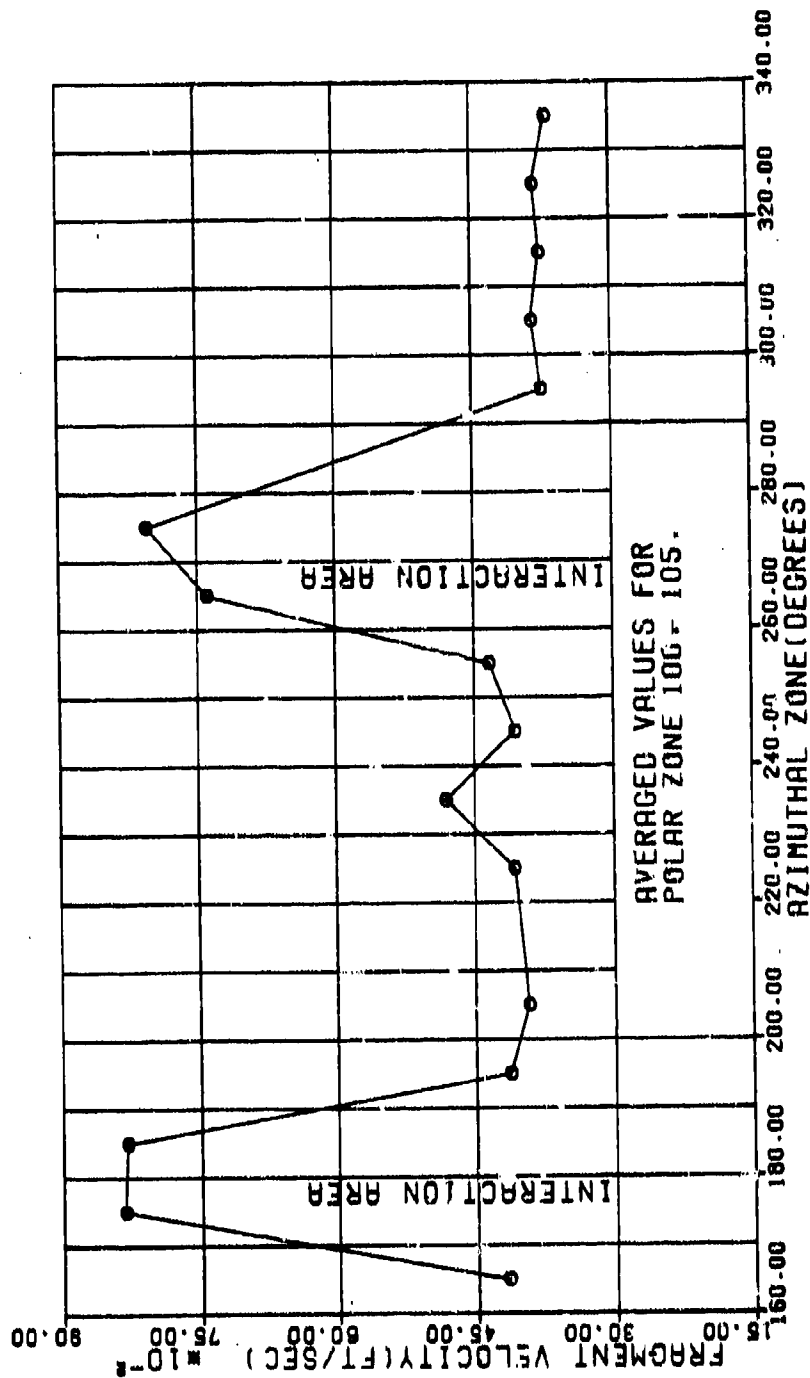


Figure 30. Average Fragment Velocities of all Firings
for Test No. QED-155-12 (Polar Zone 100°-105°)

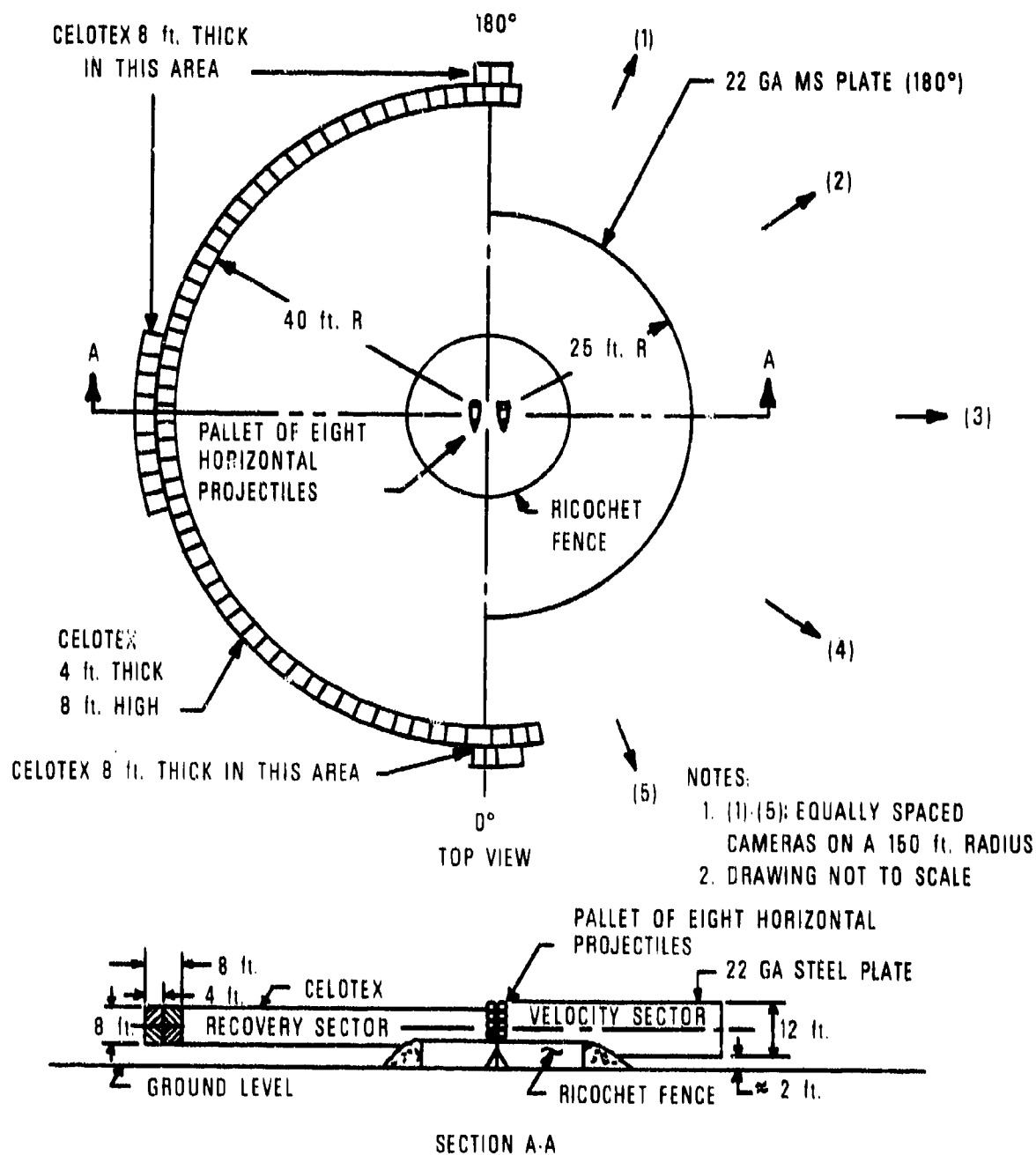


Figure 31. Polar Angle Arena Layout for Test QD-155-08

projectile interaction areas. Figure 32 is a photograph taken from a high speed motion picture film depicting the completely developed fragment jet spanning the polar zones from approximately 60° to 120°. A complete change of Celotex was required for the detonation of the second pallet of projectiles. The second firing was conducted 23 September 1976. The results were identical to the results of the first firing and, as in test QD-155-12, a third firing was not conducted.

The fragmentation data are presented in Appendix A. Figure 33 is a photograph of several fragments collected from the ground within the arena circumference. A plot of the average fragment velocities versus polar zone is presented in Figure 34.

Test QD-155-4R

This test was a repeat of test QD-155-04 and was conducted on 4 November 1976. The arena configuration was similar to that of test QD-155-04 except for the azimuthal fragment recovery sector which was changed from 15° to 11°. A repeat test was necessary because the detonations of the projectiles in the firings of test QD-155-04 were not simultaneous and the fragment data were incomplete in the projectile interaction areas. The four projectiles were detonated simultaneously with a harness device similar to the ones used in the full pallet arena tests. Photographs of the detonation sequence taken from a high speed motion picture film is presented in Figure 35. As seen from the photograph, the fragments were concentrated within a zonal sector approximately 7° azimuthal by 65° polar. Data from the one firing of this arena test and the data from the three firing arena test QD-155-04 were adequate to establish the fragmentation characteristics for the cluster of four projectiles. The fragmentation data are presented in Appendix A. A plot of the fragment velocities versus polar zone is provided in Figure 36.

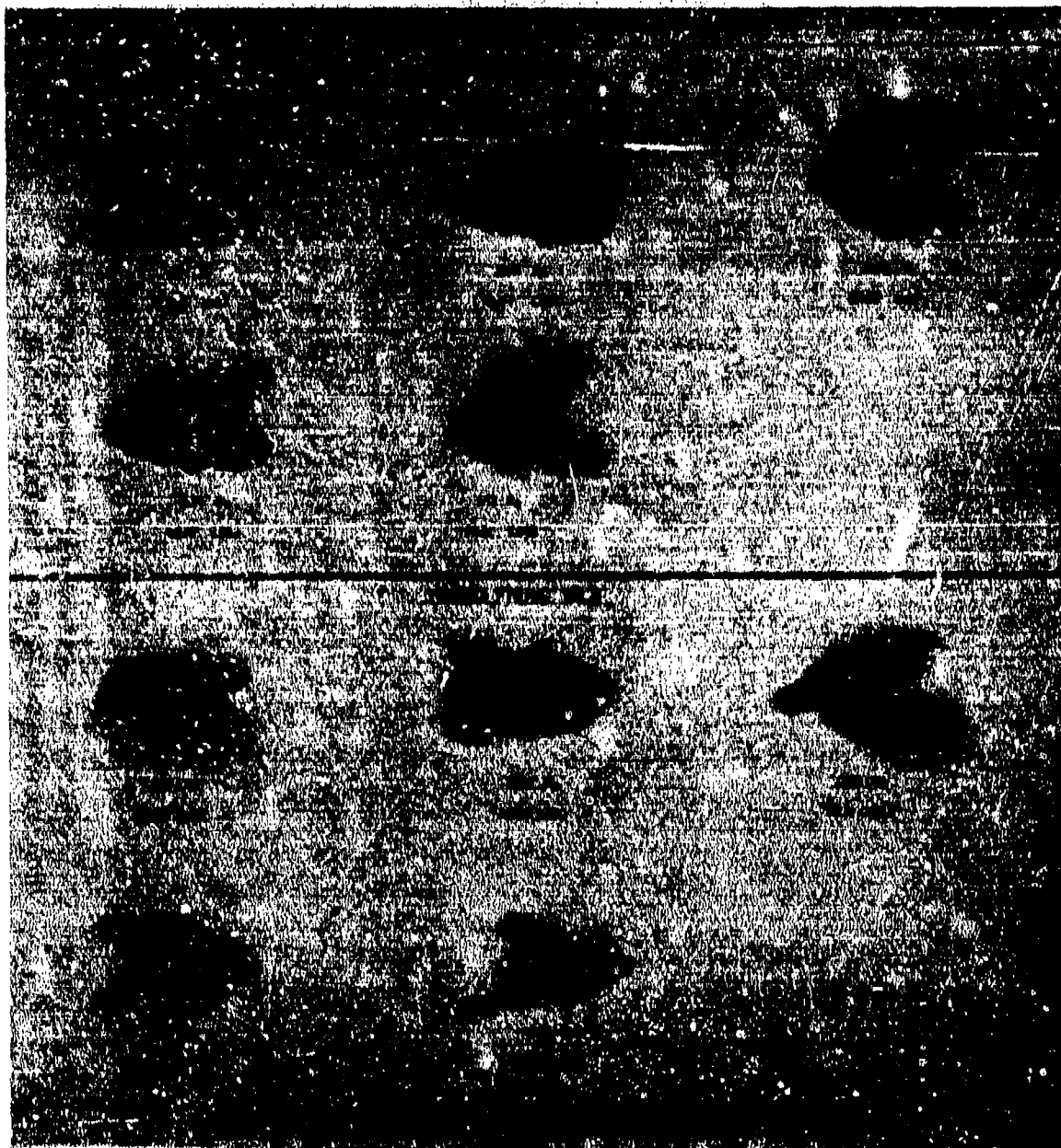
Test QD-155-10R

This test was a repeat of the azimuthal angle arena test QD-155-10 because a simultaneous detonation of the projectile cluster was not adequately achieved in the three previous arena firings. The cluster configuration for this test was identical to that for test QD-155-10. The arena layout was modified to place more emphasis on the projectile interaction areas. A sketch of the arena layout is shown in Figure 37. The cluster was detonated with the harness initiation device. Fragments were collected in 5° polar and 3° azimuthal zones bounded by 90° to 110° polar, and 345° to 15° and 75° to 105° azimuthal angles as shown in Figure 37. The velocity data were recorded in 5° polar and 10° azimuthal zones bound by 90° to 110° polar and 150° to 210° and 240° to 300° azimuthal angles.

Post test inspections of the Celotex and witness panels revealed that a characteristic fragment jet had formed at each of the 0°, 90°, 180° and 270° azimuthal angles. Photographs of the frag-



Figure 32. Completely Developed Fragment Jet Spanning Polar Zones
From Approximately 60° to 120° in Test QD-155-08



**Figure 33. Fragments Collected From the Ground
in Test QD-155-08**

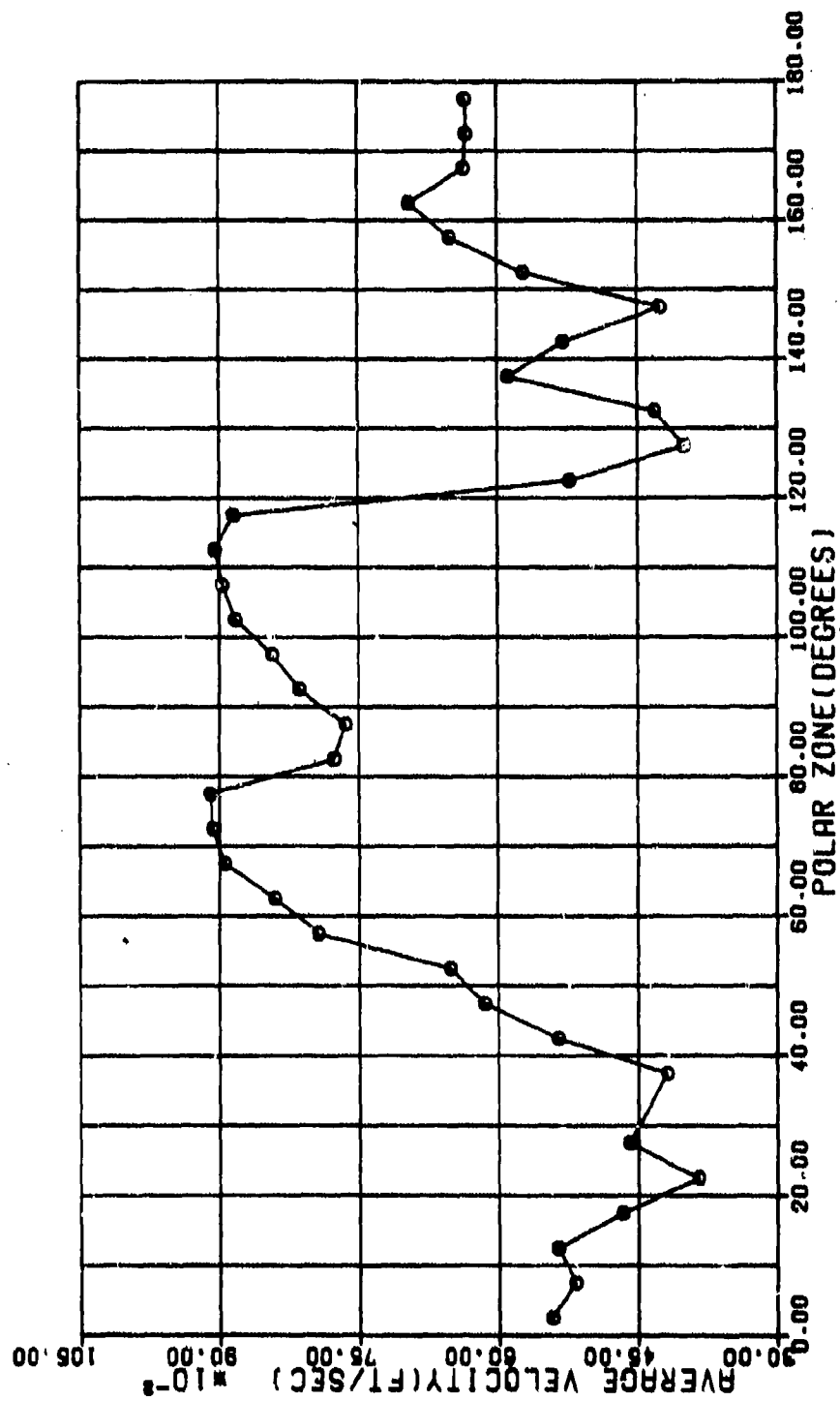


Figure 34. Average Fragment Velocities of all Firings for Test No. QD-155-08

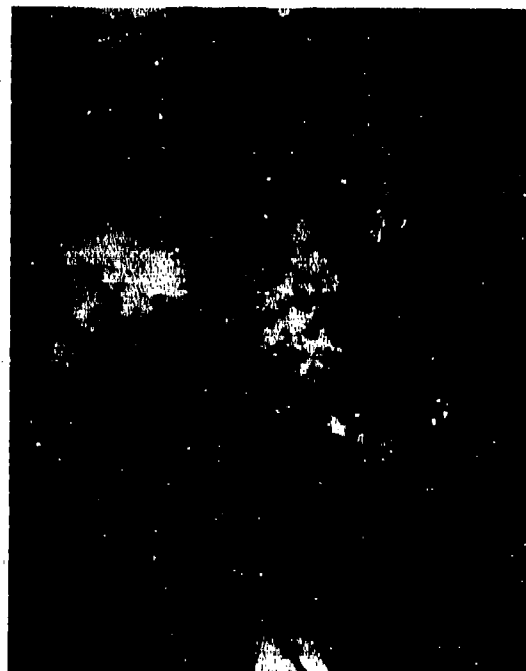
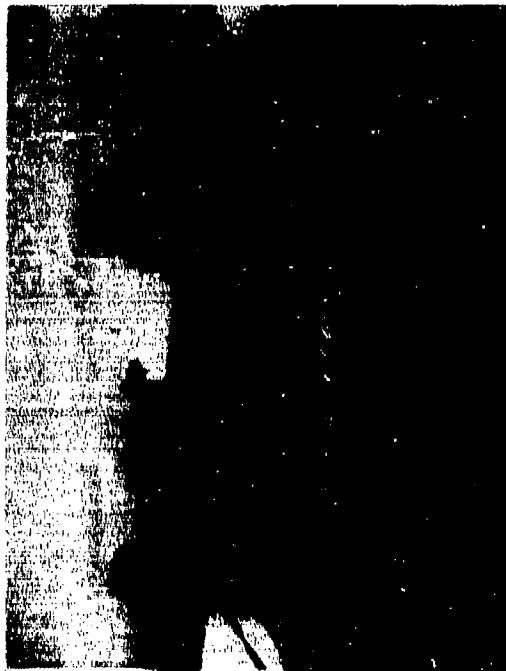


Figure 35. Formation of the Fragment Jet in Test QD-155-4R

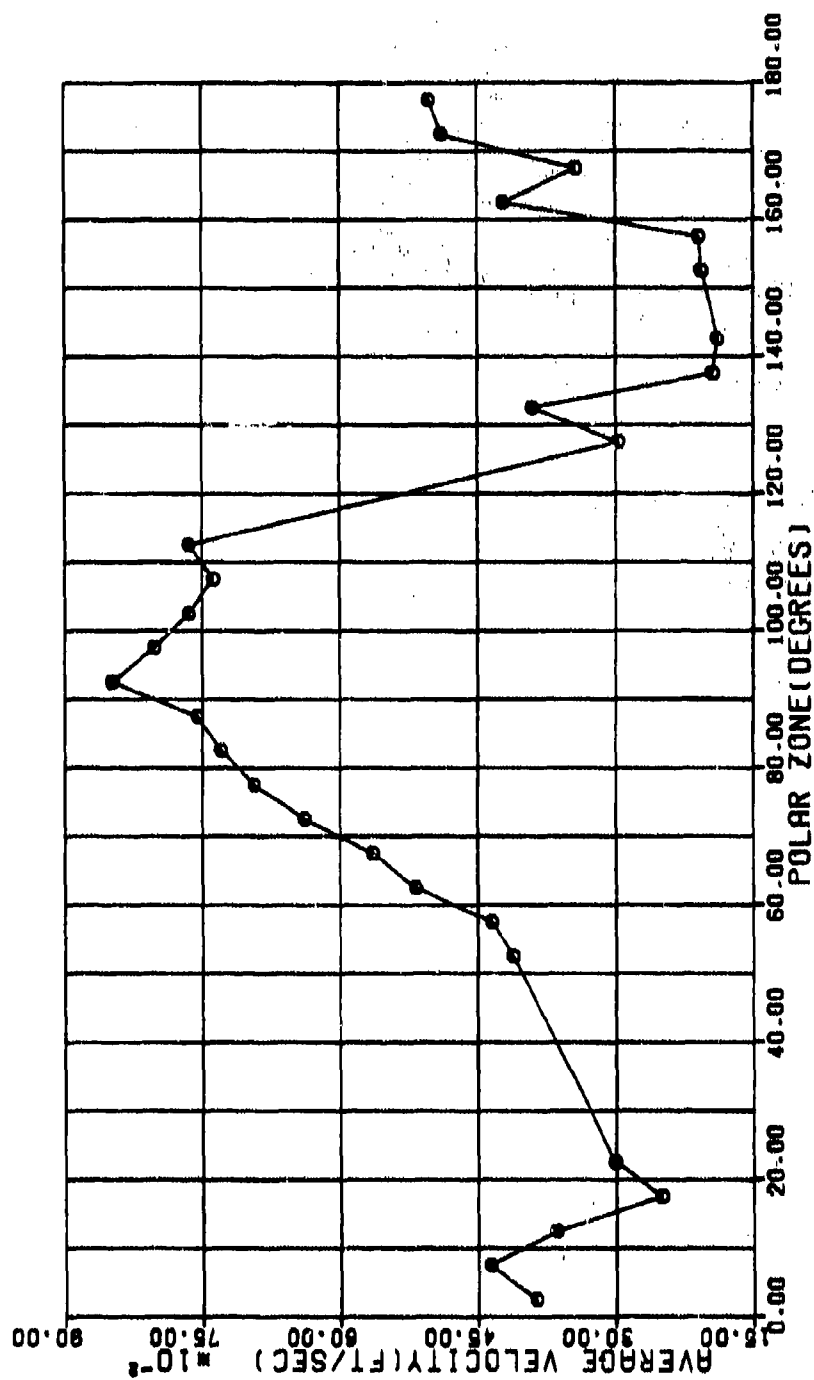


Figure 36. Average Fragment Velocities Versus Polar Zone for Test No. QD-155-4R

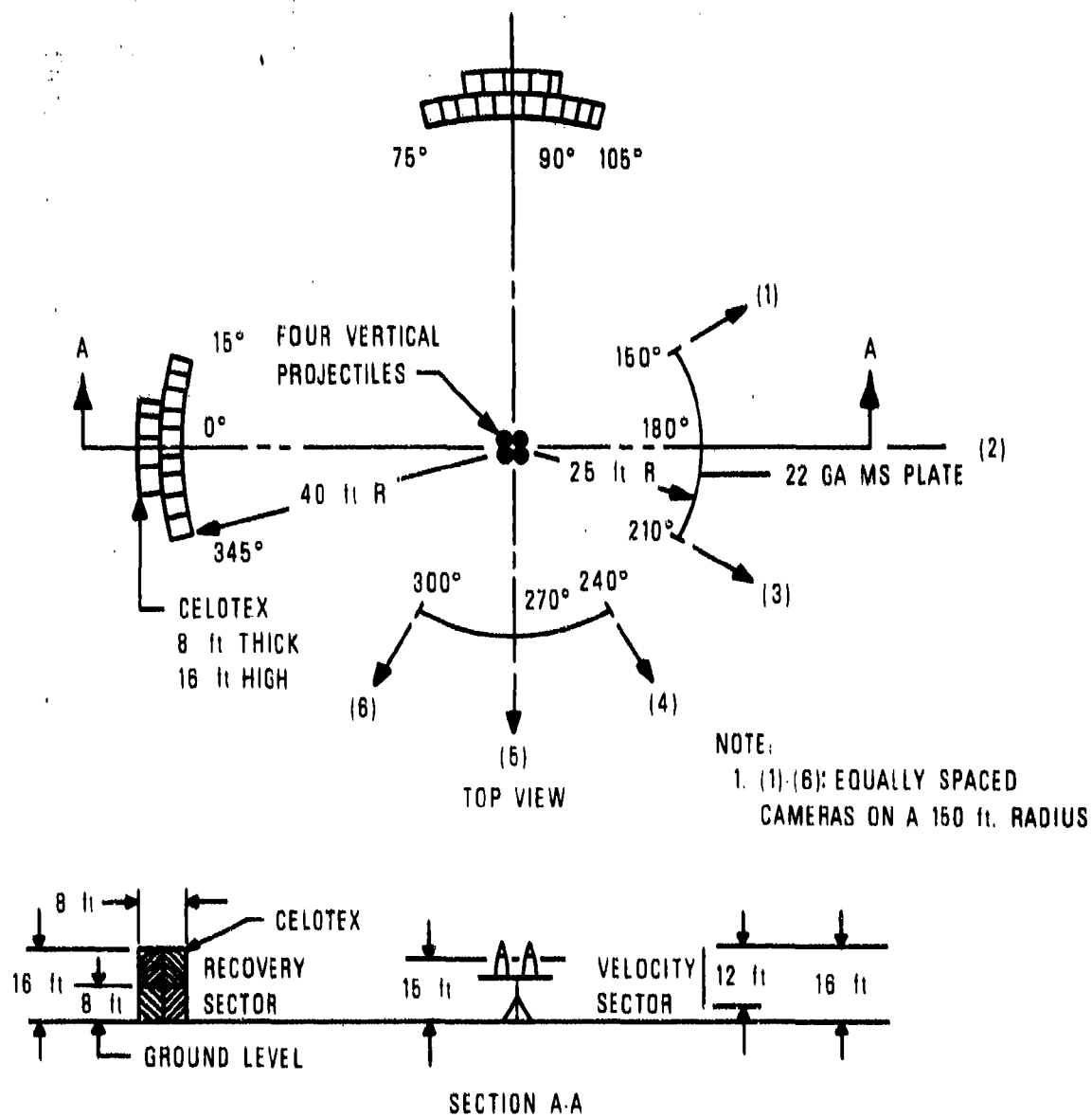


Figure 37. Azimuthal Angle Arena Layout for Test QD-155-10R

ment jets at the 180° and 270° azimuthal angles are shown in Figure 38. The fragmentation data are presented in Appendix A. A plot of each polar zone of the average fragment velocities versus azimuthal angle is presented in Figures 39 through 42. An inspection of the plots revealed the same velocity phenomena seen in the full pallet arena test QD-155-12. That is, the fragment velocities outside the interaction areas are comparable to single round data, and the fragment jet velocities increase with polar angle.

DISCUSSION

The fragmentation data from the baseline arena test were used to make comparisons with data from the multiple projectile arena tests. Even though the desired degree of detonation simultaneity was not achieved with the initiation device that was used for the first six multiple projectile arena tests, QD-155-02 through QD-155-05, QD-155-09, and QD-155-10, the fragmentation data were still adequate to characterize the projectile clusters. The small delays inherent in the functioning of the initiation device were enough to cause shifts in fragment impact patterns, but not enough to completely distort the fragment weight and number distributions, except in test QD-155-03 and QD-155-04. The fragmentation data from these tests were used for later comparisons between fragment distributions resulting from a simultaneous and non-simultaneous detonation. However, the azimuthal velocity shifts seen in test QD-155-09 and QD-155-10 did not appreciably affect the fragment data. For purpose of analysis, the velocity information was vectored into zones in which the data would have been collected in a perfectly simultaneous detonation had occurred. This was accomplished by inspecting the witness panels and Celotex and analyzing the photographic films to establish vectoral impact patterns between the velocity and fragment collection data. Inspections of the photographic films for tests QD-155-02 and QD-155-05 revealed that the fragmentation data were not affected by the azimuthal shifts in the fragment jets. These two arenas were designed to investigate the side-by-side effect of neighboring projectiles. Consequently, the projectile interaction areas were orthogonal to the Celotex and witness panels as shown in Figure 12. In general, the first six multiple projectile arena tests provided adequate fragment characterization data except for the projectile interaction areas of tests QD-155-04 and QD-155-10. A repeat firing of both arenas was planned with emphasis being placed on the interaction areas. However, so much fragmentation data had been collected from the previous arenas that it was decided to delay the repeat test until after the tests involving a full pallet of projectiles. Moreover, the repeat tests would serve as a means to investigate any unforeseen problems incurred during the conduct of the full pallet tests.

The first detonation of a full pallet of projectiles was the azimuthal angle arena test QD-155-12. Two firings were conducted with the harness initiation device shown in Figure 3 and in both arenas the fragment jets impacted the desired zones with negligible shifts. Adequate data were collected to establish complete fragment velocity profiles and fragment weight and number distributions for the entire pallet geometry. There were many large chunky fragments and projectile sections scattered about the immediate arena site. It was suspected that the simultaneity

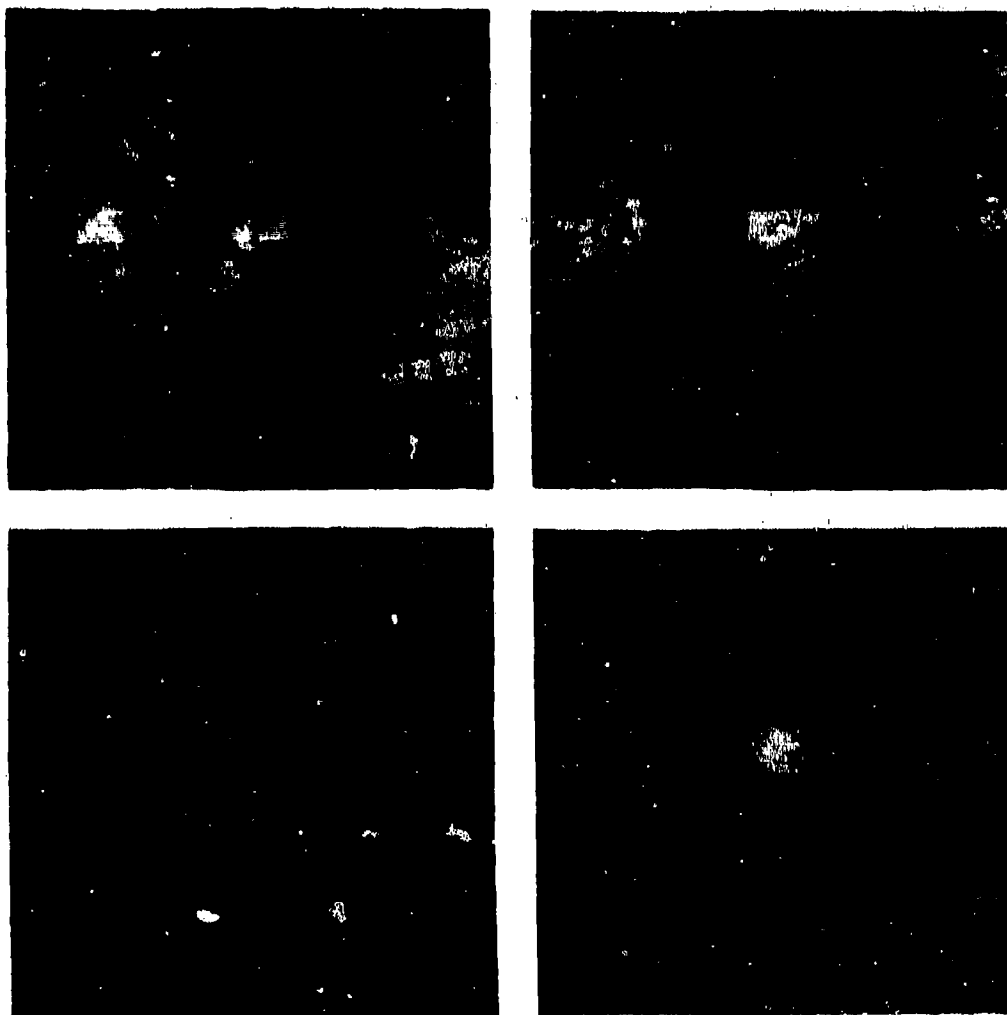


Figure 38. Fragment Concentrations in Test QD-155-10R

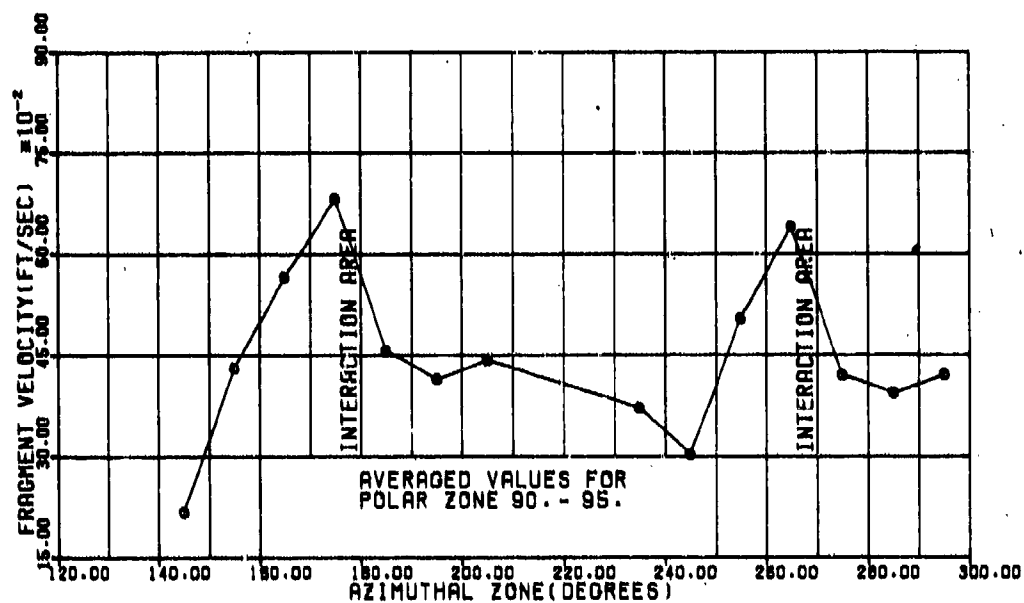


Figure 39. Average Fragment Velocities of all Firings
for Test No. QD-155-10R (Polar Zone 90°-95°)

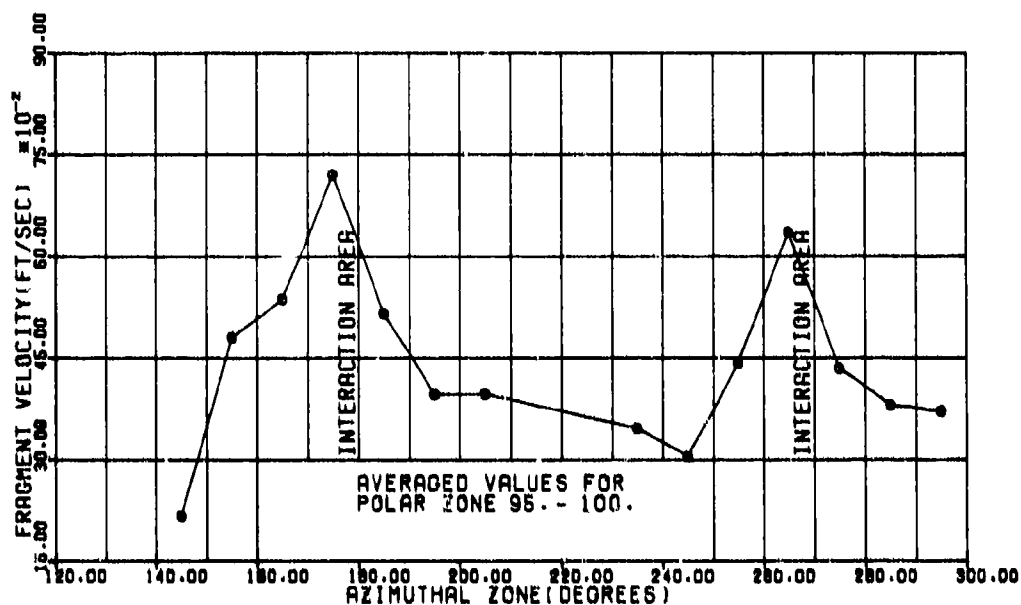


Figure 40. Average Fragment Velocities of all Firings
for Test No. QD-155-10R (Polar Zone 95°-100°)

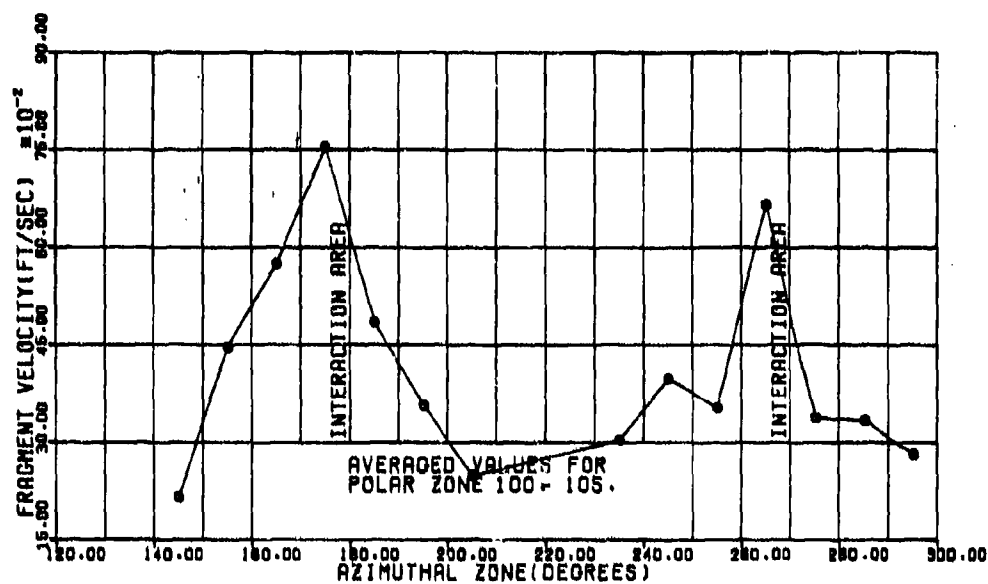


Figure 41. Average Fragment Velocities of all Firings for Test No. QD-155-10R (Polar Zone 100°-105°)

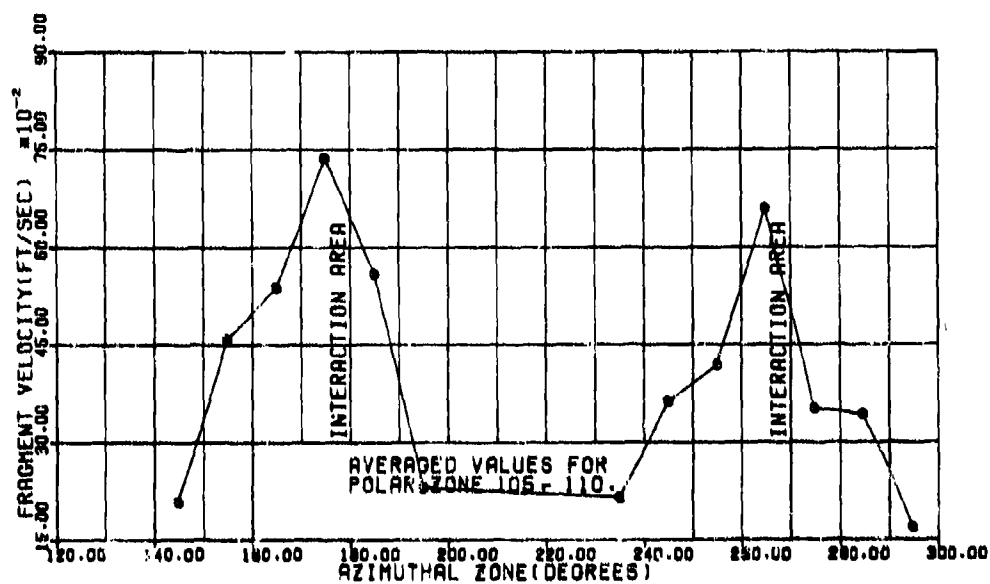


Figure 42. Average Fragment Velocities of all Firings for Test No. QD-155-10R (Polar Zone 105°-110°)

of detonation was so close to perfect that the segments of the projectiles facing the interior of the pallet were colliding with equivalent forces prior to natural fragmentation break-up. A close inspection of the fragments in Figure 25 clearly shows the natural fragmentation fracture about to occur when the fragment segmented from the main body. The outer surface of the projectile fragments (distinguishable by the rotating band) was distorted and battered by the inner pallet fragment collisions. Investigations of these fragments and other arena data led to the detonation of a full pallet of projectiles in the polar arena test QD-155-08. The fragmentation phenomena which occurred in this arena was similar to the phenomena observed in the previous arena tests. The fragment jets with the characteristic high velocities and increased fragment density formed, and the large chunky fragments were found on the ground within the arena circumference. The test data were compiled and combined with the data from azimuthal angle arena test QD-155-12. It was determined that a finer subdivision within fragment collection zones was required in the projectile interaction areas to more adequately investigate the fragment densities. The smallest possible collection zone in the full pallet arenas was 5° because of blast damage and high fragment concentrations. This was suitable for characterization purposes but it was too large to adequately map the fragment density profiles within the projectile interaction areas. Consequently, this led to the conduct of the repeat tests QD-155-4R and QD-155-10R. The arenas were modified versions of those used in the original tests. The modifications were made to fill the data gaps from the earlier tests and to provide the necessary subdivision (2° or 3° zones) for the fragment collection data in the projectile interaction areas. As shown in Figures 35 and 38, well defined fragment concentrations occurred in the predicted locations and the required data were obtained. These tests concluded the testing effort planned for the simultaneous detonation portion of the program.

ANALYTICAL STUDIES

OBJECTIVES

Concurrent with the test program, the DDESB tasked NSWC/DL to conduct supporting analytical studies. The output of the analytical effort was to be a continual review of data as it became available, interpretation of results, formulation of theory, and design of new tests to build an adequate data base. The specific objectives to be accomplished during Phase I and Phase II of the programs were:

1. Perform an information and research investigation to collect background information, prepare a data library, identify missing data and evaluate analytical models and numerical methods currently available for investigating fragment hazards from quantities of stored munitions.
2. Analyze data derived from multiple projectile detonation tests to acquire an understanding of the phenomena involved in the fragmentation process and develop a fragment characterization model.

PROGRESS

Information and Data Research

A literature search of the background information section of the work plan was conducted in the earlier months of the program and documented in the interim progress report of Reference 3. In summary, from review of the available literature, no adequately documented fragmentation data exist that can be used to model the fragment weight, number and polar zone distribution, the ballistic density or terminal distributions of far-field hazardous fragments ejected from stacked munitions.

Analysis of Test Data

All data generated from the arena tests of 155-mm projectiles were analyzed to (1) determine fragmenting characteristics of stacked munitions and develop a fragment characterization model, (2) establish an accurate means of generating fragment trajectories, and (3) develop analytical tools to produce improved safe distance quantification data and curves. To assist in following the discussion of the analysis, a matrix of the test configuration and parameters is presented in Table 1.

FRAGMENT CHARACTERIZATION MODEL

This model is based on the fragmentation data generated by the baseline and multiple projectile arena tests. Detailed comparisons of the data from this test series, as well as References 6 and 7, have led to several observations. The first of these is that the abundance of data from these tests is not sufficient to validate a model of the simultaneous detonation of a group of projectiles for the entire region of interest (polar zones 0-180°). However, there is sufficient data for polar zones 80° to 110° to develop a relatively simple model. This model can be used to design a test series that will be useful in the verification and/or expansion of this description of the simultaneous detonation of multiple projectiles.

The model that will be used for groups of two, four, and eight projectiles is shown in Figure 43. The basic assumptions are:

1. The metal in the shaded area (interior casing) does not enter into the fragment distribution, but is instead trapped in the interior area.
2. The available metal weight outside of the interaction area (Area B in Figure 43) will be equal to the metal weight from an equivalent area of a single projectile and will display fragment velocities similar to that of a single projectile.

Table 1. Arena Test Configurations

Test Number QD-155-	Type of Arena	Number of Projectiles	Projectile Orientation	Detonation Method	Fragment Recovery*		Velocity Measurements Angle (degrees)	
					Angle (degrees)		Polar Azimuthal	
					Polar	Azimuthal	Polar	Azimuthal
01	Polar	1	Horizontal	Blasting Cap Wired Series	0-180	18	0-180	27
02	Polar	2	Horizontal	Blasting Cap Wired Series	0-180	18	0-180	27
03	Polar	2	Horizontal	Blasting Cap Wired Series	0-180	18	0-180	27
04	Polar	4	Horizontal	Blasting Cap Wired Series	0-180	15	0-180	27
05	Polar	4	Horizontal	Blasting Cap Wired Series	0-180	11	0-180	27
09	Azimuthal	2	Vertical	Blasting Cap Wired Series	85-100	0-135	80-105	180-360
10	Azimuthal	4	Vertical	Blasting Cap Wired Series	85-100	20-140	80-105	200-380**
12	Azimuthal	8	Vertical	Harness Ini- tiation Device	90-100	340-140***	80-105	160-340
08	Polar	8	Horizontal	Harness Ini- tiation Device	0-180	11	0-180	27
4R	Polar	4	Horizontal	Harness Ini- tiation Device	0-180	11	0-180	27
10R	Azimuthal	4	Vertical	Harness Ini- tiation Device	90-110	75-105 345-375	90-110	150-210 240-300

*Single value indicates total coverage

**From 200° to 360° to 380° (20°)

***From 340° to 360° to 140°

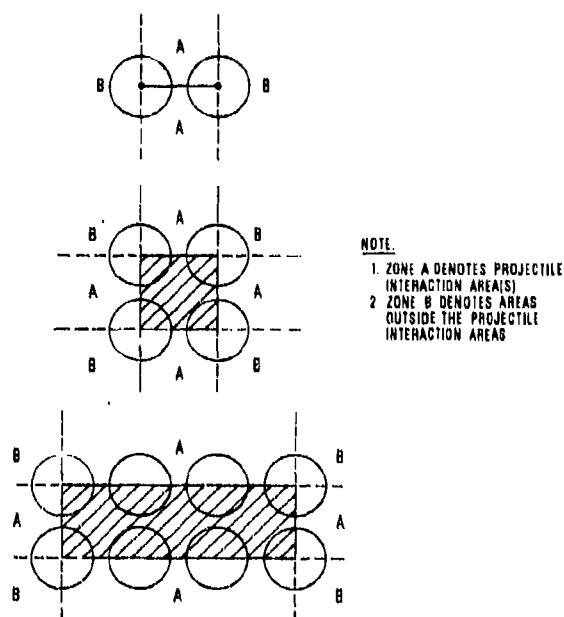


Figure 43. Fragment Characteristic Model

3. The available metal weight of the interaction area (Area A in Figure 43) will be concentrated in a narrow beam with fragment velocities larger than those of a single projectile and will be equal to the metal weight from an equivalent area of a single projectile.

4. The *slope* of the fragment weight number curves (Mott Plot) for areas A and B of Figure 43 will approximate the slope of the single projectile weight number curve.

5. The ballistic density of the fragments from areas A and B will be similar to the ballistic density of fragments produced by a single projectile.

To reemphasize, this model is based on data from the *simultaneous* detonation of stacks with a pallet spacing of seven inches center-to-center and may have to be modified for other stacking configurations or for other munitions.

Model Verification

The basic model assumptions can be verified as follows:

1. The metal in the shaded area (interior casing) does not enter into the fragment distribution, but is instead trapped in the interior area. This can be shown by investigating the amount of metal

recovered in the available azimuthal arena data from multiple detonations as compared with a single round detonation. For example, in test QD-155-12 the average weight of metal collected over the area bounded by 0° to 90° azimuthal and 90° to 100° polar was 184,804 grains. The average weight of metal collected in a similar area for a single round was 45,546 grains. This gives a ratio of 4.06. Looking at Figure 44a, the configuration model shows 1-1/4 sectors of projectile metal outside of the interior area available to be collected. Hence, the model predicts a ratio of 5.0 (1-1/4 projectiles in a 90° azimuthal sector divided by 1/4 of single projectile from the same sector). Therefore, 81% of the available metal predicted by the model was recovered. This same approach was taken in the analysis of data from test QD-155-10. The average weight of metal recovered in a 90° azimuthal sector (45° to 135° azimuthal and 85° to 100° polar) was 175,747 grains. The average weight of metal collected in a similar sector for a single round was 61,378 grains. This gives a ratio of 2.86. The model in Figure 44b shows 3/4 sectors of projectile metal available to be recovered. This yields a ratio of 3.0 (3/4 projectiles in a 90° azimuthal sector divided by 1/4 of a single projectile from the same sector). This is a recovery of 95% of the metal predicted by the model. Since there are only two projectiles on a side there is less interaction and a higher collection percentage is expected.

In both examples, the percentage of metal recovered is within the tolerance of the data. However, there is an indication that some of the metal from the denser area of 90°-100° polar zone in the interaction area is displaced beyond the 100° polar angle. This is indicated by the results of test QD-155-08 which recovered fragments from the four projectile side of a pallet over a polar angle arena. The results of this test indicated a broadened beam spray with the center of the beam spray located around the polar angle of 102.5° instead of around 98° as indicated by test QD-155-01.

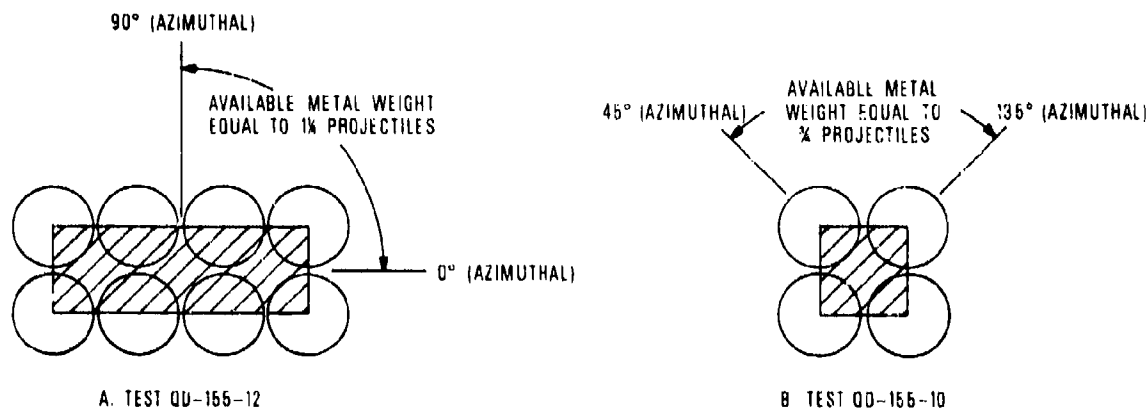


Figure 44. Available Metal Weight for 90° Azimuthal Recovery Sectors from Tests QD-155-10 and QD-155-12

In both tests there was slightly less metal recovered than predicted by the model, and therefore no indication of any contribution by the interior casing. There were also large projectile sections found lying on the ground after the multiple projectile arena tests. It was pointed out earlier in this report that the origin of these fragments was the interior casing. Figures 25 and 33 presented a sampling of these fragments from tests QD-155-12 and QD-155-08. Most of these fragments were in excess of three pounds. There were no fragments greater than three pounds collected in the Celotex from any of the arena tests, which again indicates that the shaded areas of Figure 43 do not enter into the fragment distributions of the unshaded areas.

2. The available metal weight outside of the interaction area (Area B in Figure 43) will be equal to the metal weight from an equivalent area of a single projectile and will display fragment velocities similar to that of a single projectile. This can be shown by analysis of the test data. For example, the average weight of metal recovered from those areas of test QD-155-12 that did not include any of the interaction areas was 52,221 grains. These areas consisted of a fragment recovery sector bounded by 20° to 70° and 110° to 140° azimuthal for a polar zone of 90° to 100° . The weight of metal available in a similar sector for a single round is 40,485 grains. The ratio is not 1.0 as predicted but is 1.29 which is considered to be within the tolerances of the test data. This analysis was also conducted on data from tests QD-155-02 (two side-by-side projectiles), and QD-155-05 (four side-by-side projectiles) for polar zone from 35° to 145° . Since the fragment data of test QD-155-05 was collected at 35' instead of the 25' radius of the other two tests, the fragment data for test QD-155-05 is multiplied by a correction factor of 1.4 in order to compare the data. The results were ratios of 1.14 for test QD-155-05, and 1.41 for test QD-155-02 when compared with test QD-155-01. Figure 45 displays these results pictorially and supports the model assumption. It must be noted that the cluster dimensions are small compared to the arena diameter. Similarly, as shown in Figure 46, the velocities in these regions are not significantly different from those of a single projectile.

3. The available metal weight of the interaction area (Area A in Figure 43) will be concentrated in a narrow beam with fragment velocities larger than those of a single projectile and will be equal to the metal weight from an equivalent area of a single projectile.

Figures 32 and 35 show the presence of a concentrated fragment pattern being generated at the interaction areas for tests QD-155-08, and QD-155-4R, respectively. The azimuthal width and polar spread were photographically measured for each test. A width of approximately 5° to 13° with a polar spread of 75° to 120° was recorded for QD-155-4R. Similarly, for QD-155-08, a width of approximately 5° to 20° with a polar spread of 50° to 120° was recorded. In both cases, the azimuthal width of the fragment concentration increased with polar zone. The fragment velocities for these concentrations were plotted and presented earlier in this report as Figures 34 and 36. The fragment velocities, in some cases, were shown to be as much as two times the fragment velocities from similar zones of a single projectile. The degree of increase for the number of fragments in these concentrations can be shown by plotting the recovered metal weight for each concentration of a particular polar zone versus azimuthal angle. Since test QD-155-08 was a polar arena

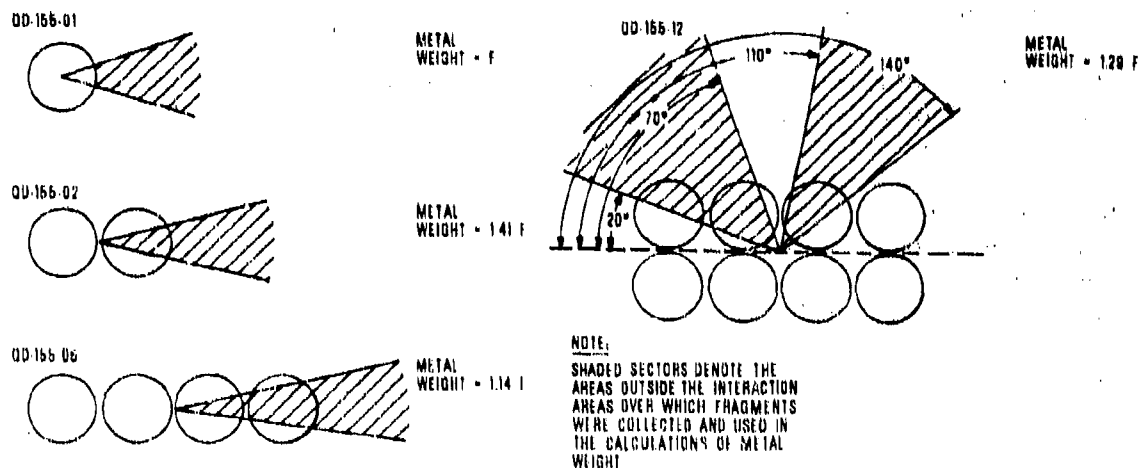


Figure 45. Comparison of Available Metal Weight Outside the Interaction Area to an Equivalent Area of a Single Projectile

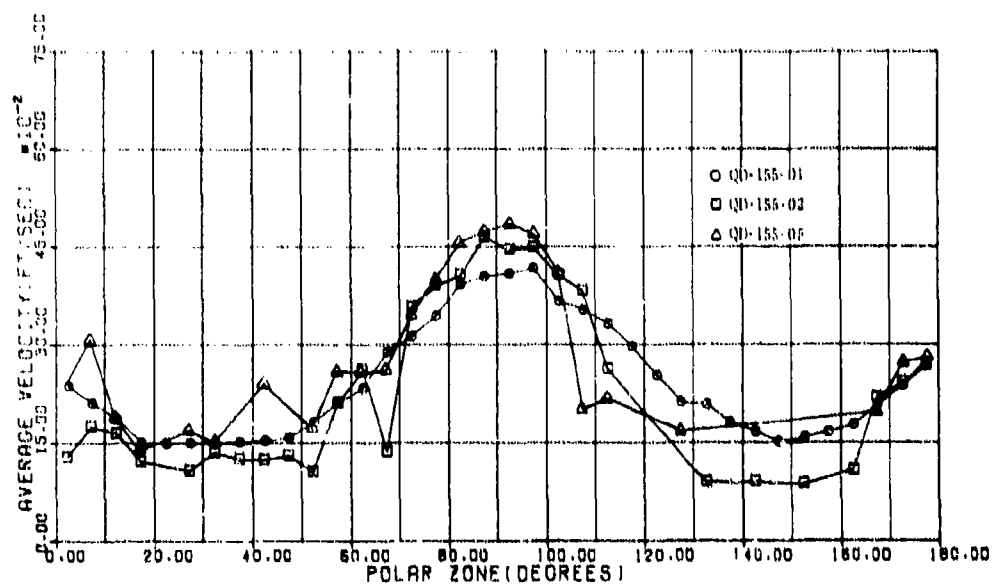


Figure 46. Average Fragment Velocities of all Firings for Tests QD-155-01, -02, and -05

and was not designed for azimuthal coverage, the data from test QD-155-12 was used. Figure 47 is a plot of the collected fragment weight versus azimuthal angle for polar zones 90° to 100°. As shown by the plot, the amount of recovered metal in the interaction areas (0° and 90° azimuthal) is significantly larger than all other areas. However, it can be shown by using this data that the amount of available metal in the interaction area is equal to the metal weight of an equivalent area of the single projectile. For example, the 0° interaction area shown in Figure 48 includes 180° of available metal. However, due to the fragment recovery zones, the test data includes an extra 20° of metal as shown in Figure 48. Therefore, the test data will be compared to the metal weight corresponding to 200° of a single projectile of a similar zone. Two hundred degrees of metal weight from a single projectile at polar zone 90° to 100° (QD-155-01) yields 101.2×10^3 grains. The recovered metal weight of test QD-155-12 at the zero degree interaction area for the same polar zone is 124.2×10^3 grains. Similarly, the 90° interaction area (Figure 48) can be handled in the same manner, if an extra 40° of metal is considered. This results in metal-weight corresponding to 580° of single projectile which is 293.5×10^3 grains. The collected weight for this area is 408.5×10^3 grains. These values are considered to be within the tolerance of the data and support the assumption.

4. The *slope* of the fragment weight number curves (Mott Plot) for areas A and B of Figure 43 will approximate the slope of the single projectile weight number curve.

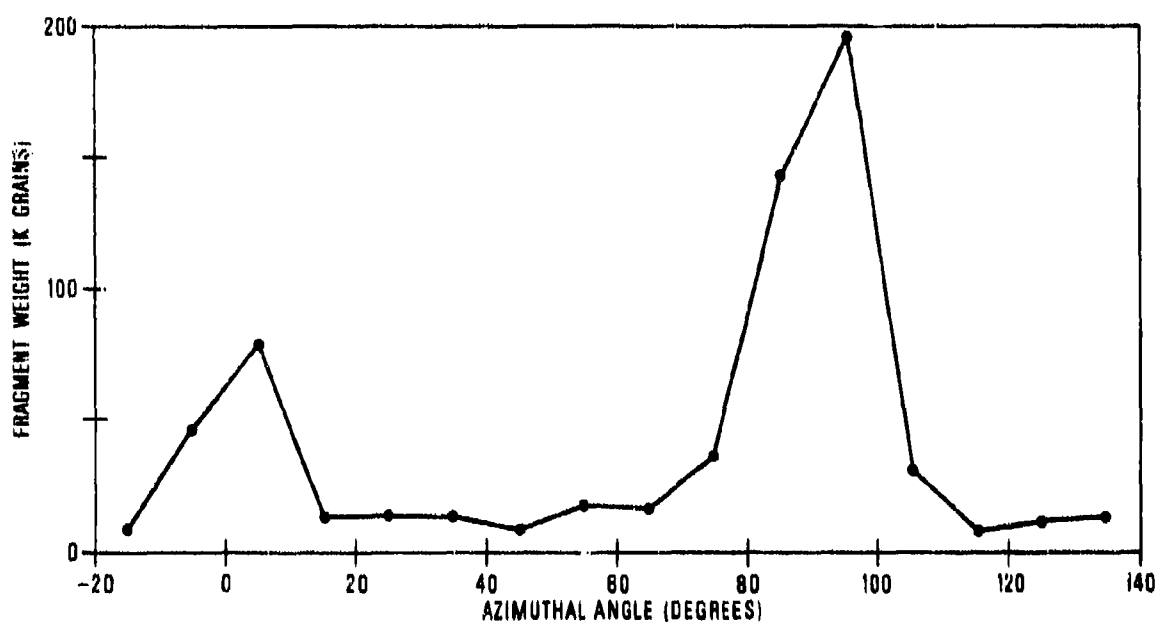


Figure 47. Fragment Weight Versus Azimuth Angle
for Test QD-155-12, Polar Zones 90°-100°

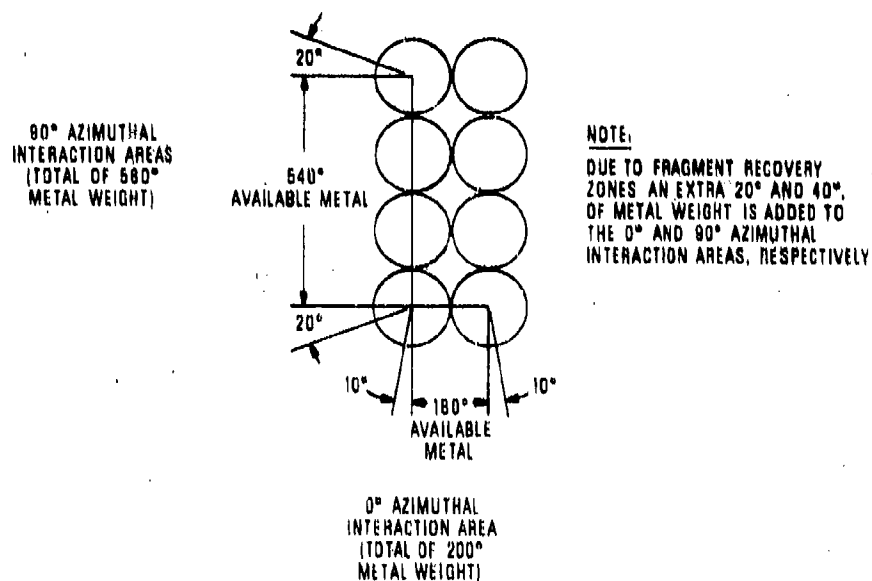


Figure 48. Available Metal Weight for Interaction Areas of Test QD-155-12

A comparison of the Mott Plots (fragment number greater than weight (W) versus the square root of W) for areas A and B of tests QD-155-01 (single projectile), QD-155-08 (full pallet polar arena), and QD-155-12 (full pallet azimuthal arena) in polar zones 90°-100° is presented in Figure 49. It is clearly apparent that the slopes of the curves for these tests are approximately equal. As a further verification of this assumption, the average fragment weight (μ) shows no significant variation between either the single round or areas A and B of the full pallet.

Figure 50 presents the Mott Plots and average fragment weight (μ) for all the polar arena tests in polar zones 60° to 90°. The slopes of the curves and average fragment weight are similar except for test QD-155-05. The reason(s) for the differences in the data from QD-155-05 is (are) unknown.

In summary, for simultaneously detonated projectile clusters, there does not appear to be any significant difference in the slope of the fragment weight distribution curves between a single projectile and the regions A and B.

5. The ballistic density of the fragments from areas A and B of Figure 43 will be similar to the ballistic density of fragments produced by a single projectile.

Figure 51 presents a comparison of the average fragment weight W versus γ (average presented area/ W) for tests QD-155-01, QD-155-02 and QD-155-08. As clearly shown, there is no significant

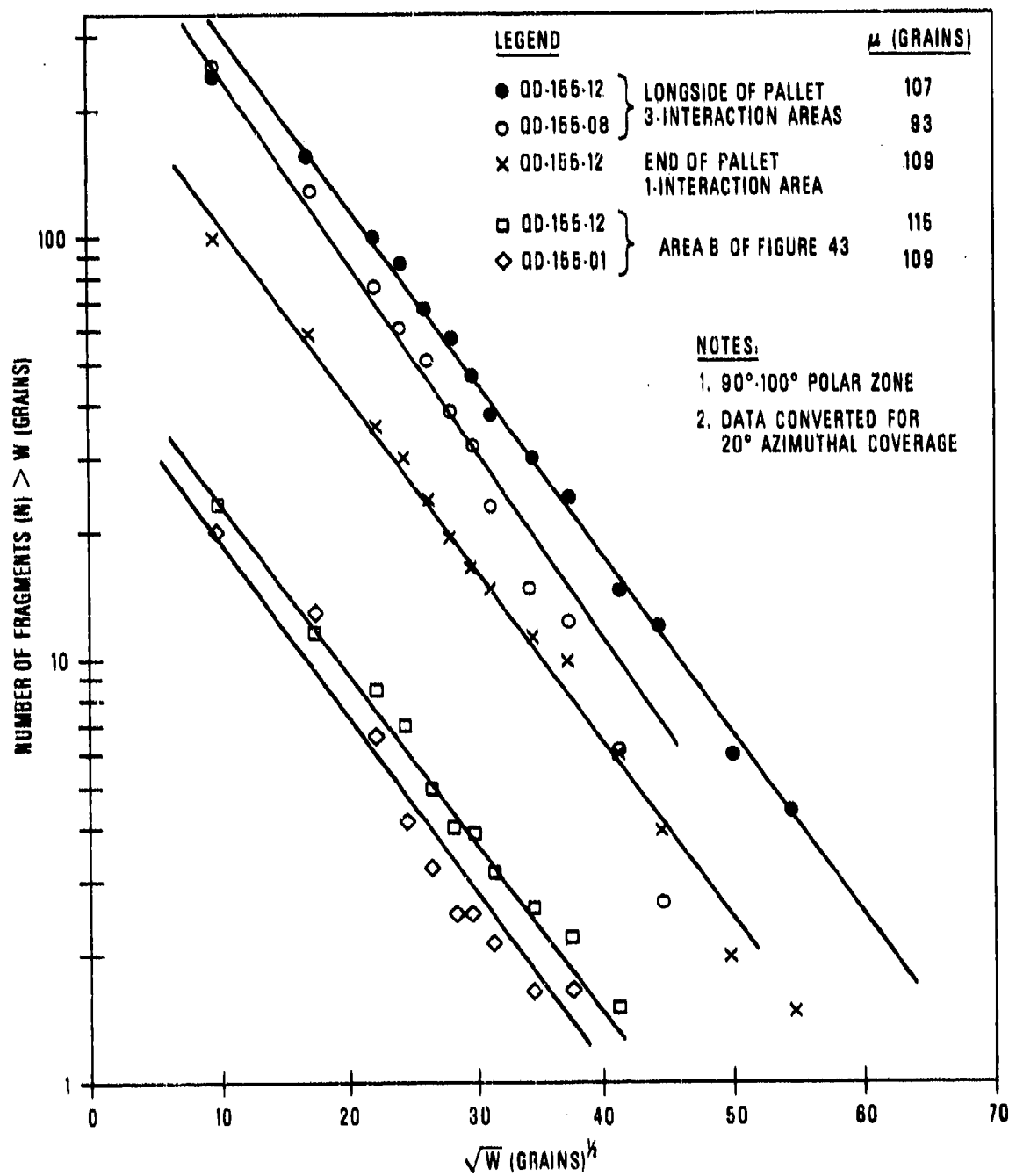


Figure 49. Mott Plot Comparison for Tests (QD-155-01, -08 and -12)

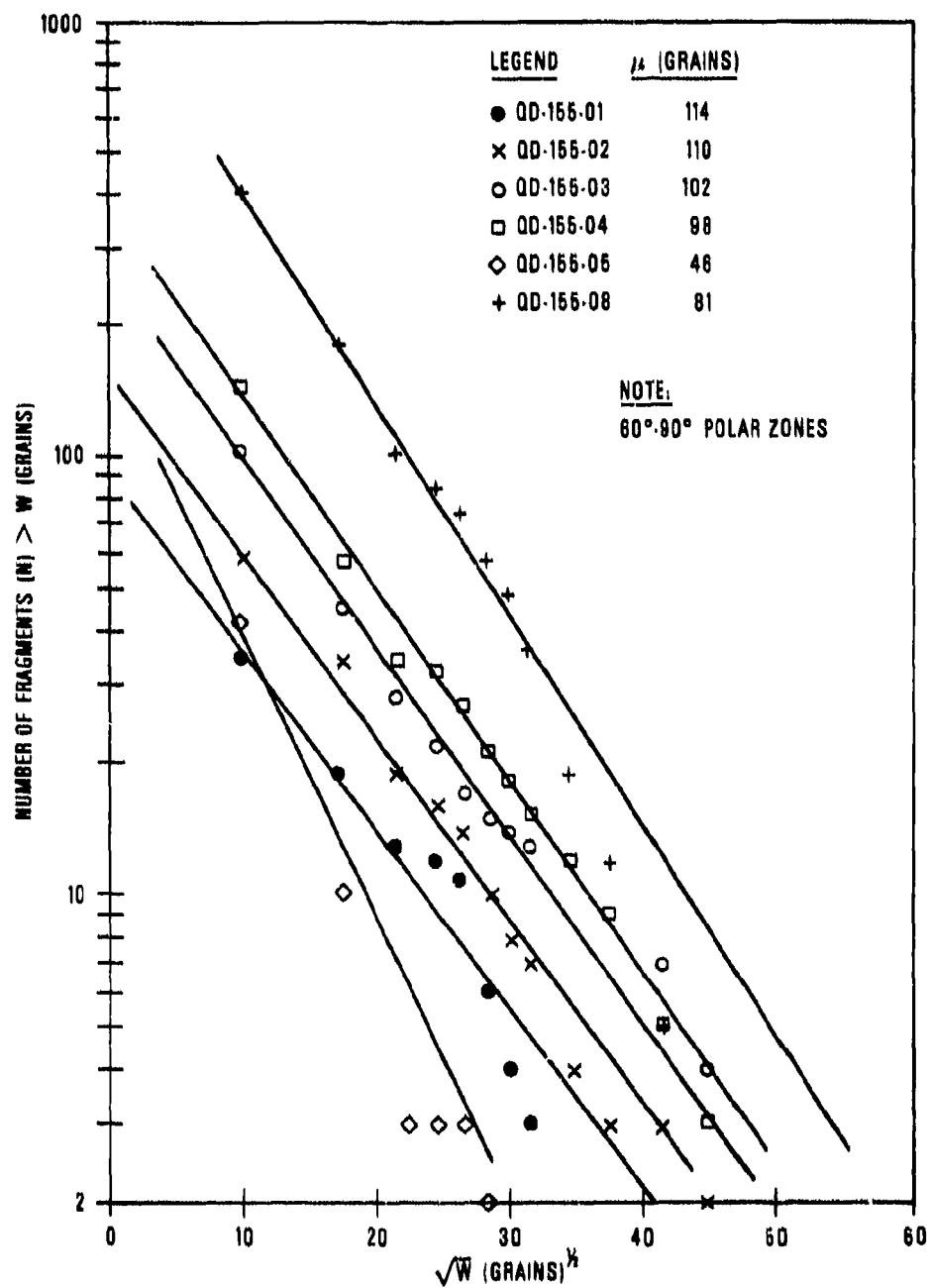


Figure 50. Mott Plot Comparison for Tests QD-155-01, -02, -03, -04, -05, and -08

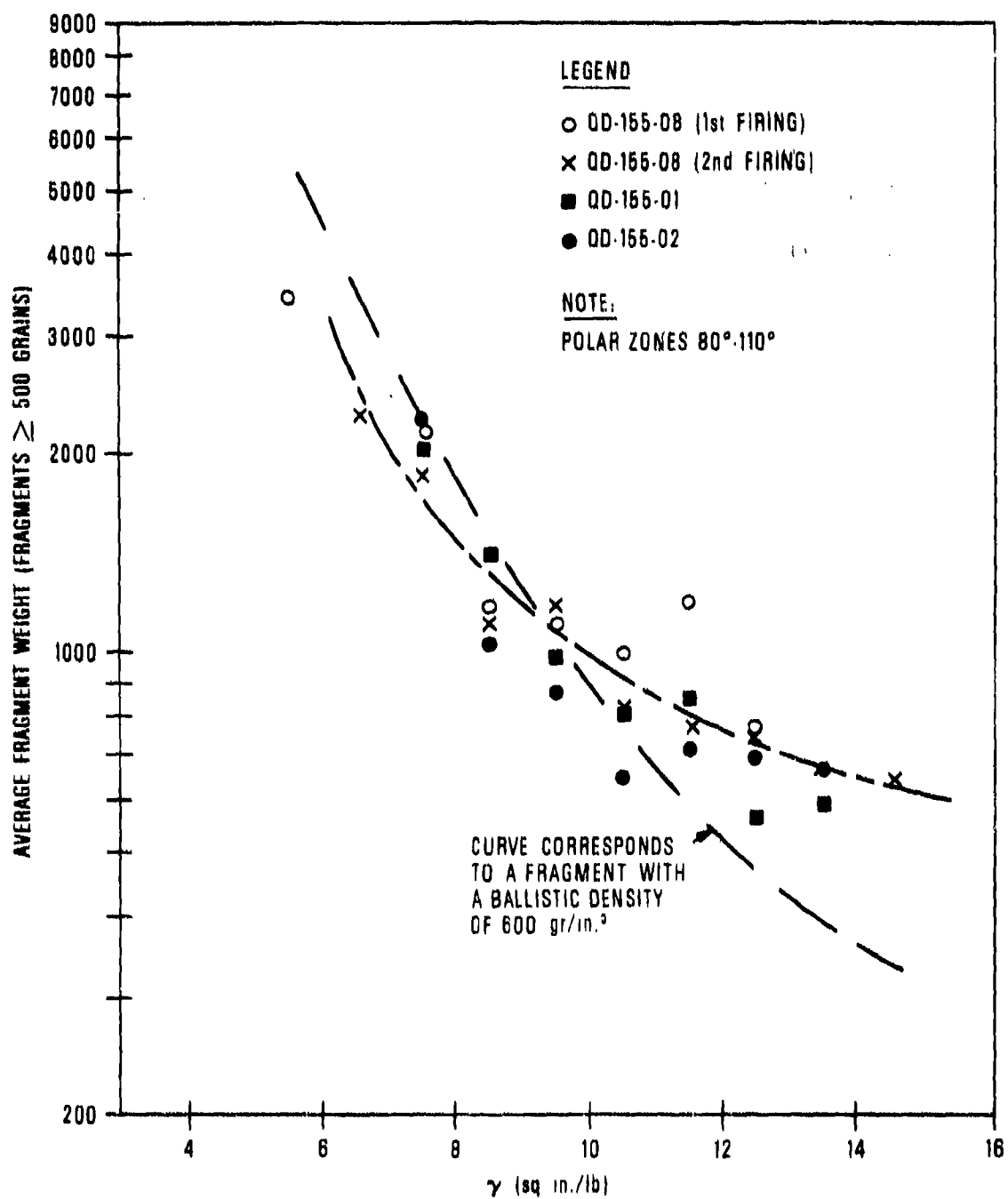


Figure 51. Average Fragment Weight Versus Gamma for Test QD-155-01, -02 and -08

difference in the ballistic density curves observed from these tests even though the data points are from the interaction areas of QD-155-08, the non-interaction areas of a multiple detonation test QD-155-02, and the single round test QD-155-01. The deviation past γ of 10 sq in./lb is due to the elimination of fragments weighing less than 500 grains from presented area measurements. The measurements were not taken for the lighter fragments because they were not important in calculating quantity-distance values, and would have drastically increased the cost and time required to obtain the test results.

FAR-FIELD FRAGMENT DENSITY

TRAJECTORY AND RANGE INVESTIGATION

This section presents the results of the research conducted on the parameters used to generate fragment trajectory and range data. The parameters investigated are (1) drag coefficient (C_D), (2) ballistic density (k), (3) ejection angle (α), and (4) ejection velocity (V). A discussion of these parameters follows:

Fragment Drag Coefficient (C_D)

A fragment which travels to the far-field spends the majority (75%) of its flight time at subsonic velocity. Consequently, the accuracy of the value used for the subsonic drag coefficient is critical to the accuracy of a trajectory calculation. However, the values for the subsonic and transonic drag coefficient from the most commonly used curves (Reference 8) are the result of lump sum averaging of all experimental measurements below Mach 1.0. Figure 52 compares the standard shell fragment curve (Reference 8) to the curve generated when the same experimental measurements are averaged for small increments of mach number. The reduction in the drag coefficient in the subsonic and transonic region (as compared to the standard curve) is significant and will result in an increase of 10-15% in fragment range and kinetic energy calculation over the values generated using the standard subsonic shell fragment drag coefficient. The trajectory and range calculations in this report are based on the reduced subsonic drag coefficient ($C_D = 0.92$), since it is felt that this method of calculating the drag coefficient is more reasonable.

Ballistic Density (k)

Figures 53 and 54 present plots of fragment weight (W) versus gamma (A/W) for a single projectile (QD-155-01) and a full pallet detonation (QD-155-08). The ballistic density curve (600 gr/in.³) normally used for characterizing a 155-mm projectile and the curve for a ballistically efficient steel cube (1075 gr/in.³) are also plotted for comparative purposes. It is evident from the

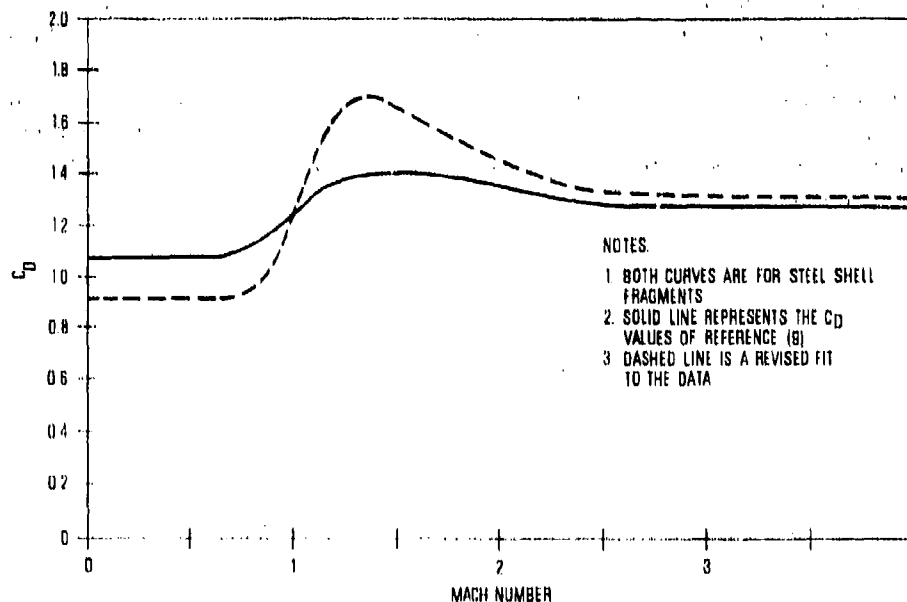


Figure 52. Coefficient of Drag Versus Mach Number for Steel Shell Fragments (Reference 8)

plots that a significant number of fragments from both tests have ballistic densities approaching that of a cube. Use of the 600 gr/in.^3 curve clearly will be inaccurate for a study of far-field fragment density. The expected range of the more ballistically efficient fragments will be approximately 44% greater than that of the "typical" ($k = 600 \text{ gr/in.}^3$) 155-mm fragment.

Ejection Angle (α)

Figure 55 presents computer generated fragment ranges as a function of ejection angle for several gamma values. As shown by the curves the range for each gamma is essentially constant for the optimum ejection angles between 5° and 45° . These angles correspond to polar zones 45° through 85° for an upright projectile.

Ejection Velocity (V)

As previously shown in the data, fragment velocities in the interaction area of a full pallet are 7000 to 9000 ft/s, approximately twice that of a single projectile.

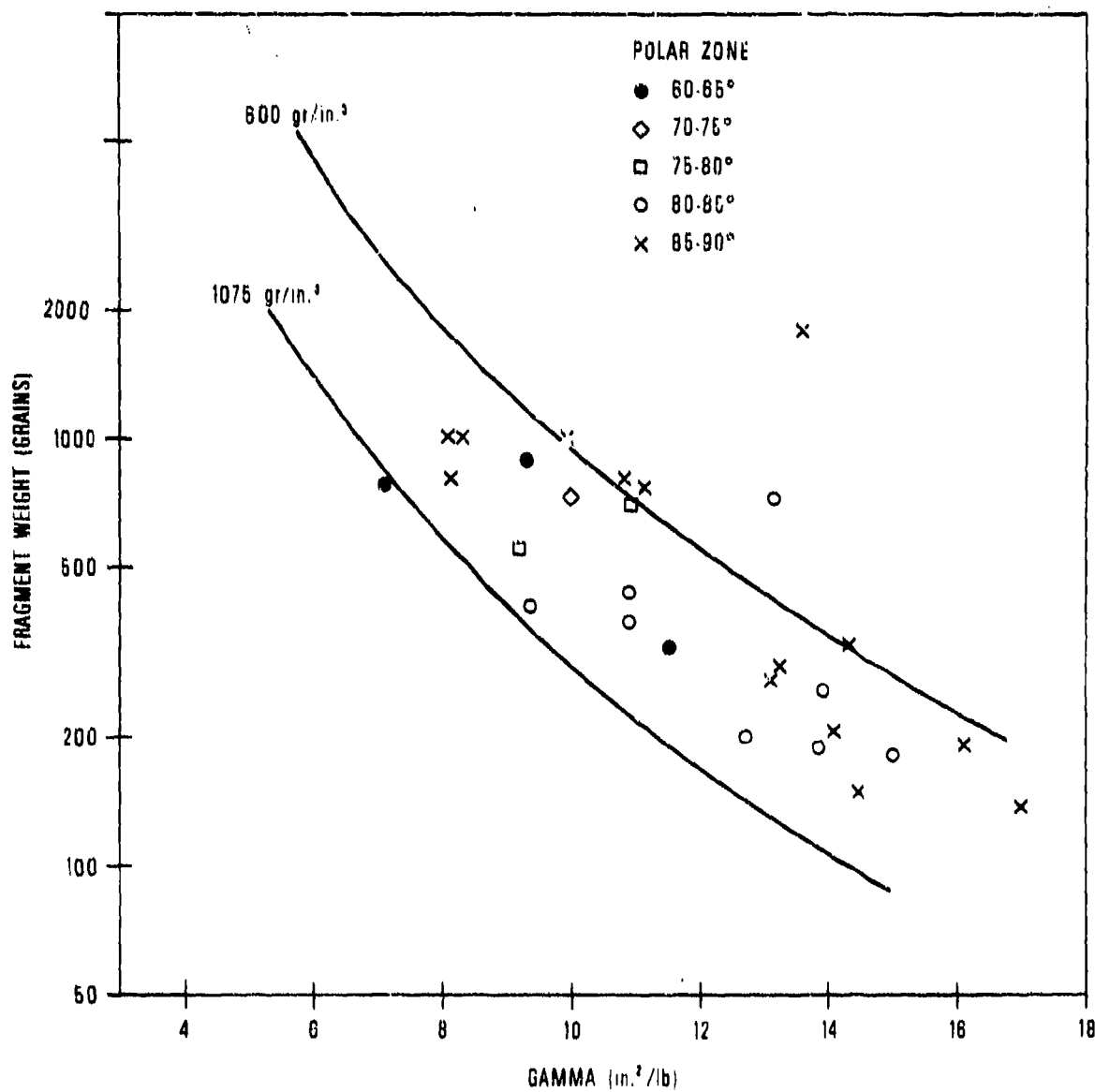


Figure 53. Fragment Weight Versus Gamma for Test QD-155-01

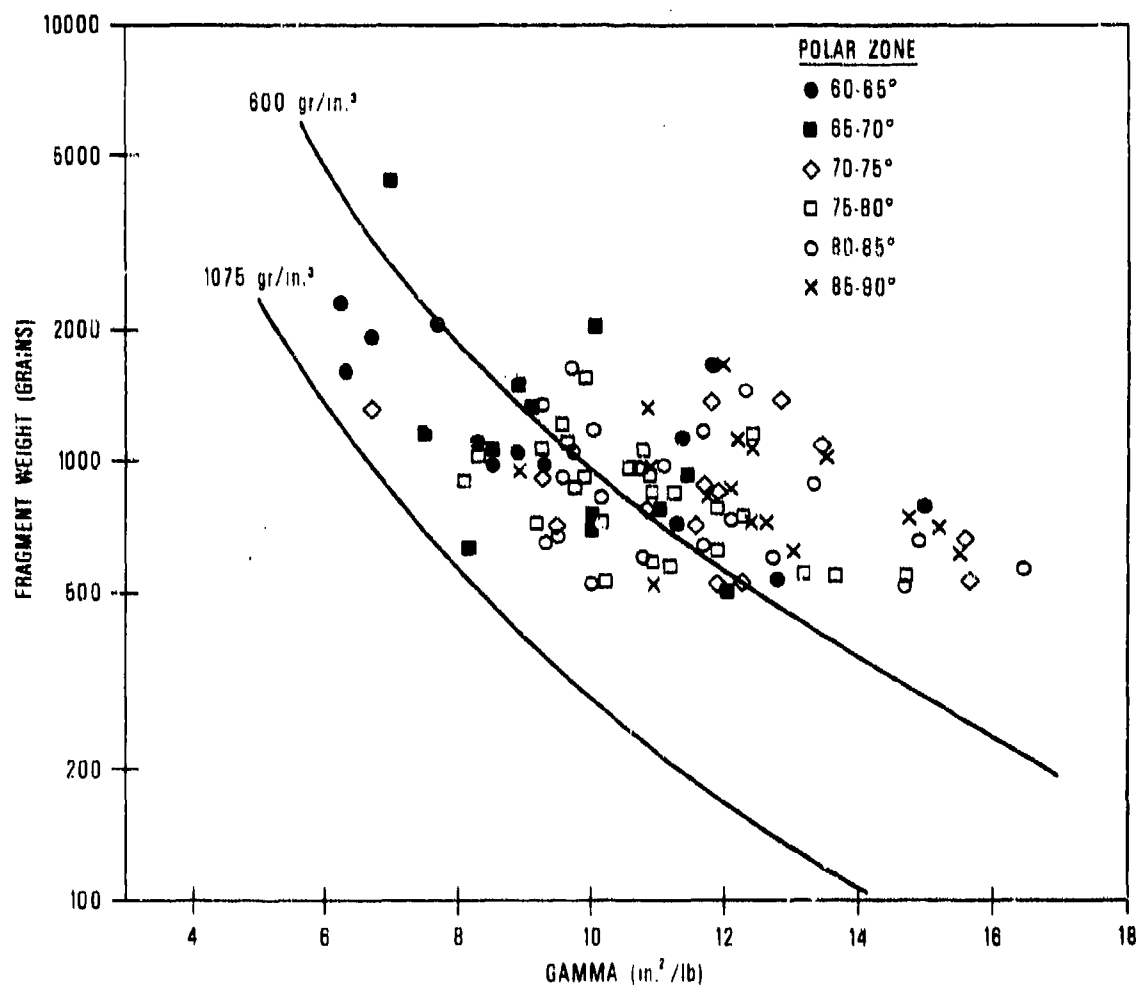


Figure 54. Fragment Weight Versus Gamma for Test QD-155-08

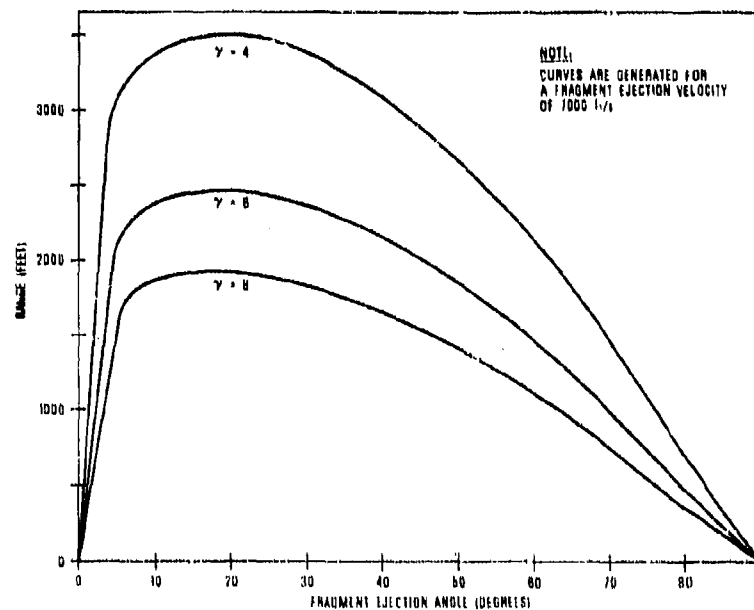


Figure 55. Fragment Range Versus Ejection Angle as a Function of Gamma

To summarize, revising the currently used values of C_D and k will result in an increased predicted range of approximately 66%. Considering the approximate doubling in fragment velocity for the full-pallet of 155-mm projectiles results in a cumulative increase in range of approximately 90% for fragments ejected from the interaction area.

DEVELOPMENT OF EMPIRICAL RELATION

This section presents the development of an empirical relation defining the far-field density of fragments produced by the simultaneous detonation of 155-mm projectiles. The relation is developed from the following two equations.

Number of Fragments

Figure 56 presents a plot of the number of fragments with γ less than γ_1 , versus $\gamma_1^{-1/3}$ for the full pallet tests QD-155-08 and QD-155-12 and the single projectile test (QD-155-01). The obvious similarity in the slopes of the curves led to the development of the relation

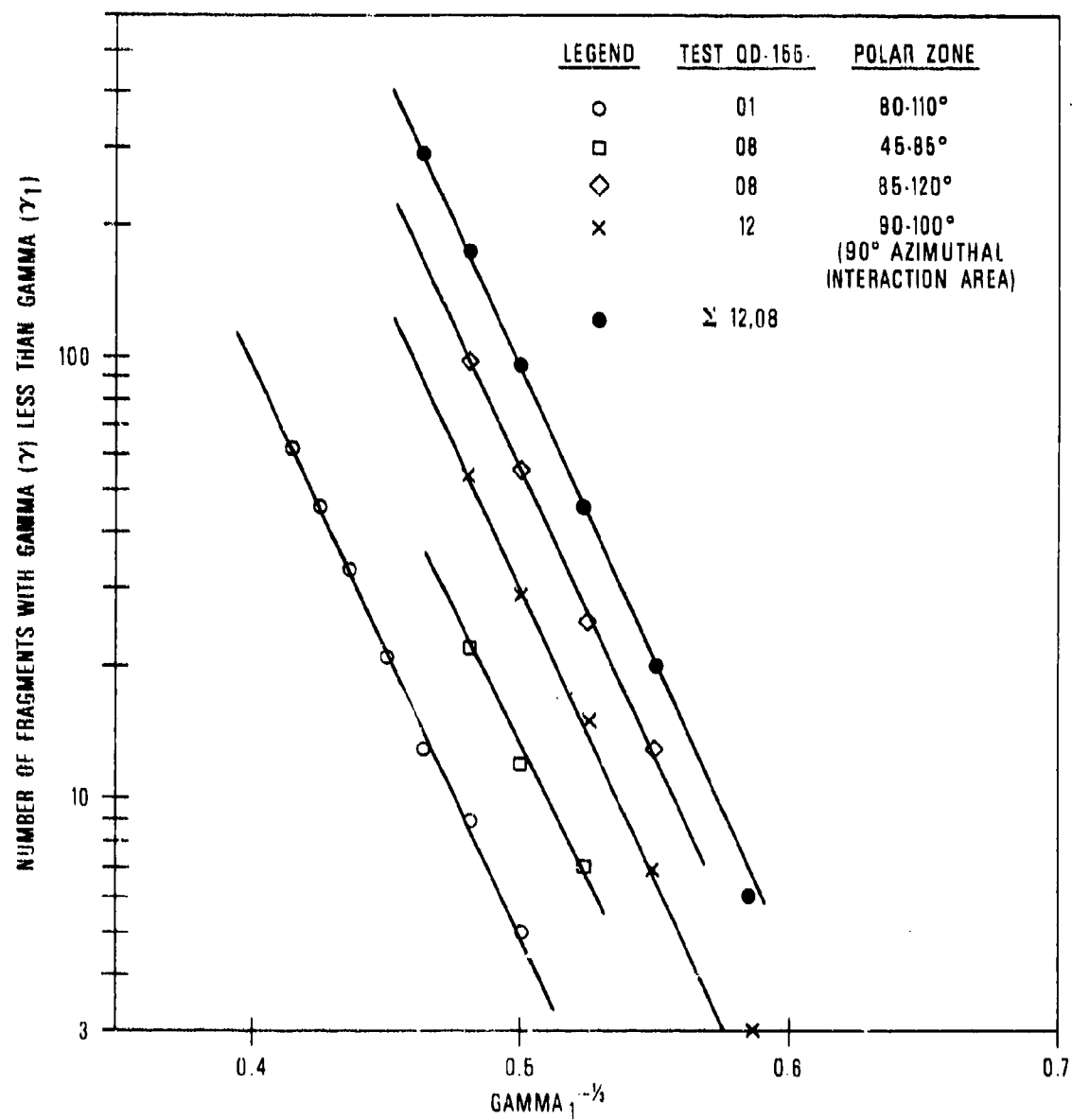


Figure 56. Relationship for the Number of Fragments Less Than Γ_1 Versus $\Gamma_1^{-1/3}$ for Tests QD-155-01, -08, and -12

$$N(\gamma < \gamma_1) = N_0 e^{-\left(\frac{31450}{\gamma_1}\right)^{1/3}} \quad (1)$$

where

$N(\gamma < \gamma_1)$ = number of fragments with γ less than γ_1

N_0 = constant of proportionality (dimensionless)

Several calculated values of N_0 (normalized per degree of azimuth) are presented below:

Test No. QD-155-	Polar Zone	N_0
01	80°-110°	0.57×10^6
08	45°-85°	4.10×10^6 (three interaction areas)
08	85°-120°	17.50×10^6 (three interaction areas)
12	90°-100°	5.20×10^6 (three interaction areas)

Fragment Range

A good analytic fit to computer generated ranges for values of gamma from 2 to 20 sq in./lb and velocities from 3000 to 10000 ft/s is provided by,

$$R = \left[7920 \left(\frac{V}{1000} \right)^{0.275} \right] \gamma \left[0.18 \left(\frac{1000}{V} \right)^{0.275} - 1 \right] \quad (2)$$

Fragment Density

The fragments of interest are produced in the interaction area at a velocity of approximately 8700 ft/s between polar zones 45° to 85° (optimum launch angle for upright projectile). Substituting for V in equation (2), the range R as a function of γ is

$$R = 14358 \gamma^{-0.901} \quad (2a)$$

or solving for γ ,

$$\gamma = 41100/R^{1.11} \quad (2b)$$

Substituting this value of γ into equation (1) yields

$$N(R > R_1) = N_0 e^{-0.912 R_1^{0.37}} \quad (3)$$

where R_1 corresponds to γ_1 through equation (2b) and

$N(R > R_1)$ = number of fragments with range R greater than R_1 in an area of one degree width (see Figure 57).

As previously mentioned N_0 is a constant developed from the full pallet test data and is representative of three interaction areas for a full-pallet test. In order to make equation (3) useful for any number of projectiles, the analytically determined N_0 is defined as

$$N_0 = N_{IA} N_{0A} \quad (4)$$

where

N_{IA} = number of interaction areas

N_{0A} = N_0 per interaction area

N_{IA} = NUMBER OF INTERACTION AREAS

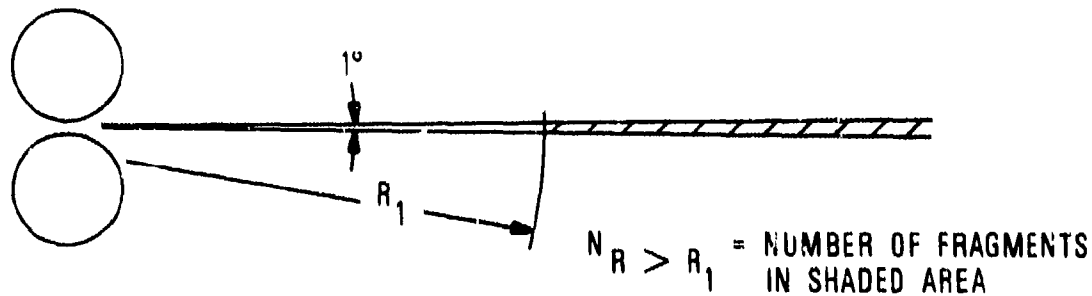


Figure 57. Representation of Far-Field Fragment Area

Substituting equation (4) into equation (3) yields

$$N(R > R_1) = N_{oA} N_{IA} e^{-0.912 R_1^{0.37}} \quad (5)$$

The desired relation for the number of fragments per unit area as function of range R is of the form

$$\frac{dN}{dA} = \frac{dN}{dR} \frac{dR}{dA} \quad (6)$$

where

dN/dA = number of fragments per unit area

The subscript 1 on R will now be dropped.

Differentiating equation (5) with respect to R yields

$$\frac{dN}{dR} = \left[-0.337 R^{-0.63} \right] N_{oA} N_{IA} e^{-0.912 R^{0.37}} \quad (7)$$

It is obvious that

$$dA = \frac{2\pi R dR}{360^\circ} \quad (8)$$

or

$$\frac{dR}{dA} = 57.3/R \quad (8a)$$

Substituting (7) and (8a) into equation (6) yields the final relation

$$\frac{dN}{dA} = \frac{-19.3 N_{oA} N_{IA}}{R^{1.63}} e^{-0.912 R^{0.37}} \quad (9)$$

The accuracy of equation (9) can be evaluated by comparing the predicted fragment density for the stack configuration of test ESKIMO 1 to the fragment collection data from the test (Reference 9). The best data is for the West Side Wall row of 275 projectiles. Collection data for

fragments weighing 875 grains or more are presented for ranges up to 3000 feet. A good fit to this data is the curve provided by equation (9) for $N_{oA} = 2.44 \times 10^6$ ($N_{IA} = 274$) as shown in Figure 58. A similar plot is also presented of the density of fragments greater than 875 grains using N_{oA} from test QD-155-08 and the ESKIMO I stack configuration ($N_{IA} = 274$). Both curves fit the ESKIMO I data exceptionally well considering the uncertainty in the simultaneity of the projectile detonation for test ESKIMO I. The significance of the fit indicates that far-field fragment density data may be obtained through small-scale testing (several pallets) instead of the more expensive large-scale detonations.

IMPLICATIONS FOR QUANTITY-DISTANCE REQUIREMENTS

It is desirable to relate the far-field fragment densities predicted by equation (9) to the mass detonating munition quantity-distance requirements of Reference 1 for inhabited buildings. This can be accomplished by making suitable modifications and substitutions into both equation (9) and the safe stand-off equation from Reference 1 given by

$$R = KW_{TE}^{1/3} \quad (10)$$

where

R = safe stand-off distance (i.e., Range) (ft)

K = constant of proportionality ($\text{ft}/\text{lb}^{1/3}$) dependent on value of W_{TE}

W_{TE} = total stored explosive weight (lb)

This equation can be made to represent the number of projectiles in a stack (N_p) by substituting the product of N_p and the explosive weight per projectile (W_{PE}) for W_{TE} such that

$$R = K(N_p W_{PE})^{1/3} \quad (10a)$$

or solving for N_p

$$N_p = \frac{R^3}{K^3 W_{PE}} \quad (10b)$$

A similar approach is used to solve equation (9) for N_p . First, solving for the number of interaction areas, N_{IA} , to yield

$$N_{IA} = \frac{-dN}{dA} \left[\frac{R^{1.63} e^{0.912R^{0.3}}}{19.3 N_{oA}} \right] \quad (9a)$$

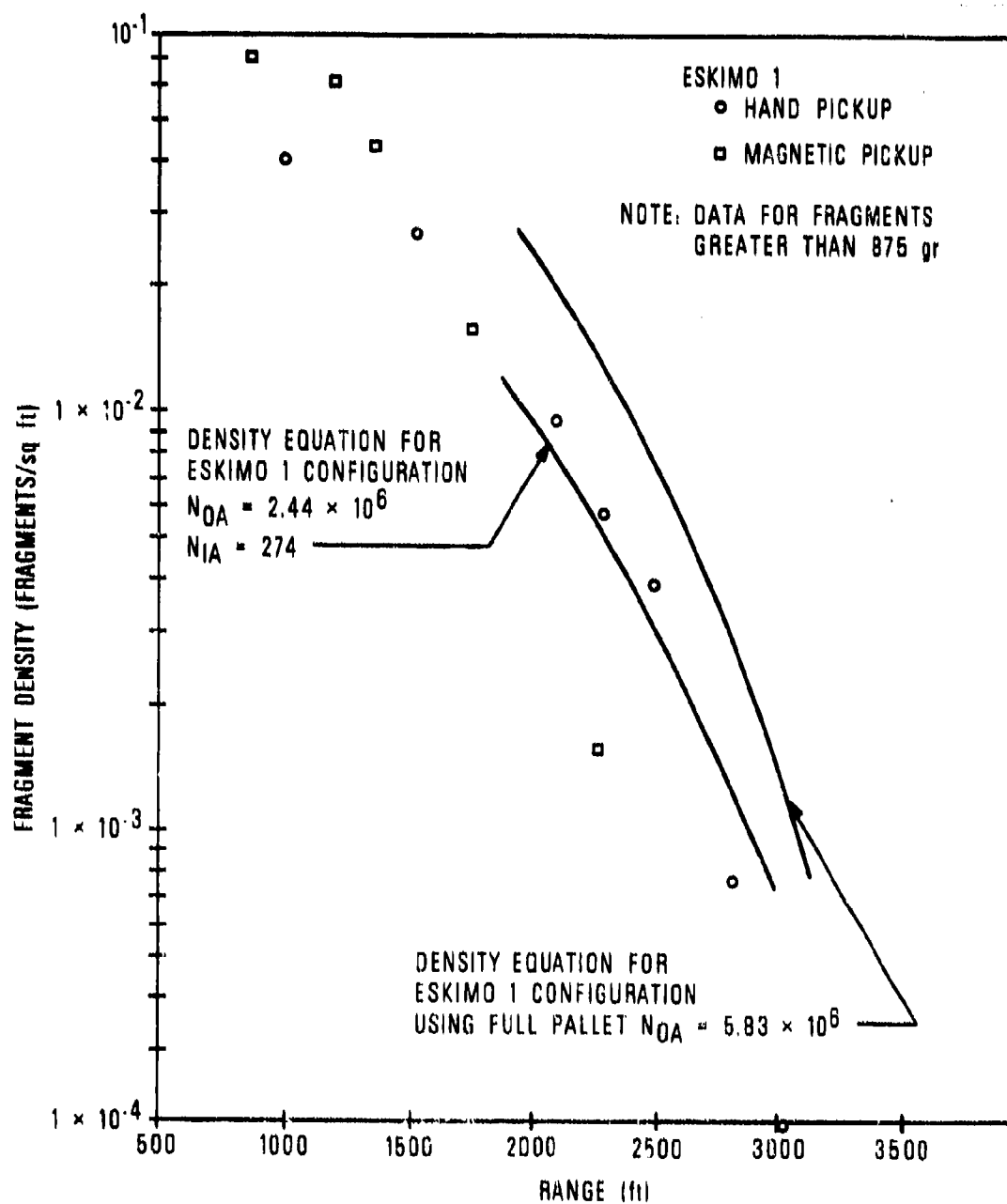


Figure 58. Far-Field Fragment Densities Versus Range for ESKIMO 1 and Test QD-155-08

The number of interaction areas is related to the stack configuration by

$$N_{IA} = (N_p / N_H N_w) - 1 \quad (11)$$

where

N_H = height of stack (no. of projectiles)

N_w = width of stack (no. of projectiles)

Substituting equation (11) into equation (9a) and solving for N_p yields

$$N_p = N_H N_w \left[1 - \left(\frac{dN}{dA} \right) \frac{R^{1.63} e^{0.912 R^{0.37}}}{19.3 N_{0A}} \right] \quad (9b)$$

The value chosen for the fragment density dN/dA in equation (9b) is one fragment per 600 sq ft which represents the maximum allowable hazardous fragment density from Reference 1. A hazardous fragment is defined as one which possesses a terminal kinetic energy of 58 ft-lb or greater. Substituting this density and the value of N_{0A} (1.37×10^6) for test QD-155-08 reduces equation (9b) to

$$N_p = N_H N_w \left[1 - 6.27(10^{-11}) R^{1.63} e^{0.912 R^{0.37}} \right] \quad (9c)$$

Figure 59 presents the allowed number of projectiles (N_p) calculated for several stack configurations ($N_H \times N_w$) by equation (9c) (one fragment/600 sq ft) and the allowed number of projectiles calculated from the standard quantity-distance relation of equation (10b). Comparison of the curves shows that for equivalent ranges; (1) the standard quantity distance over-estimates the allowed number of projectiles, and (2) the configuration of the stack is a significant determinant of the allowed number of projectiles.

It should be realized that the one fragment per 600 sq ft curves in Figure 59 represent both hazardous and non-hazardous fragments. In order to provide an understanding for the number of hazardous fragments as a function of range, the data from tests QD-155-01, QD-155-08 and QD-155-12 were analyzed using the following relation for the minimum weight of a hazardous fragment (W_{HF})

$$W_{HF} \geq 198.63 \gamma \quad (12)$$

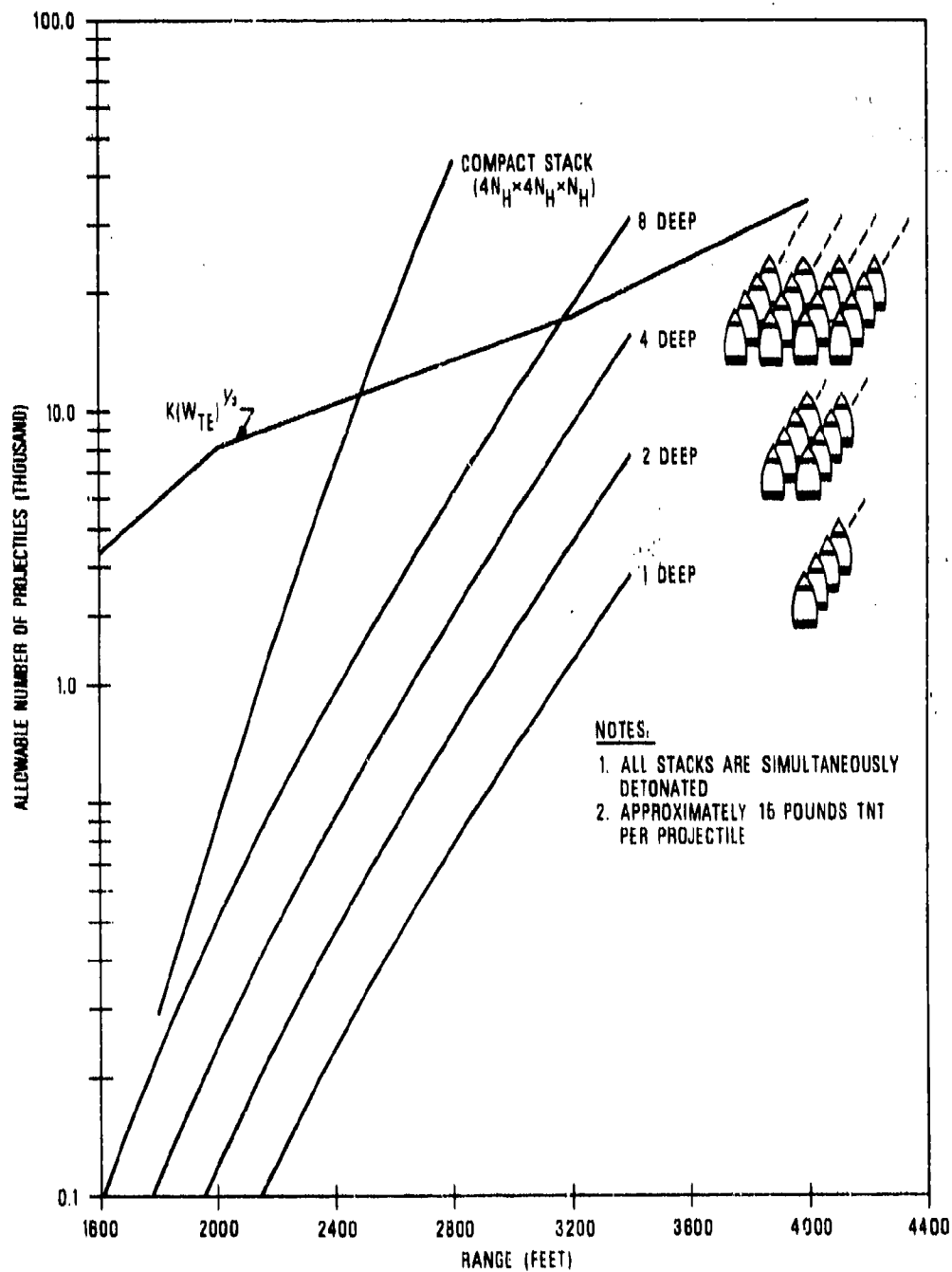


Figure 59. Allowable Number of Projectiles Versus Range

That is, any fragment weighing at least 198.63 times its measured gamma will be hazardous in the far-field. This equation is developed from the equations for terminal velocity in free fall and kinetic energy.

Figure 60 presents the results of applying equation (12) to the test data and plotting the percent of hazardous fragments as a function of gamma and range. It is obvious from the curve that the majority of far-field fragments (R greater than 2300 ft) will be hazardous and that all fragments falling beyond 3100 ft will be hazardous. Referring to Figure 60 for R - 3100 ft (100% hazardous fragments) further emphasizes the over-estimation of the allowed number of projectiles by the safe stand-off distance equation as compared to the number of projectiles allowed by the fragment density curves.

EFFECTS OF NON-SIMULTANEOUS DETONATION

The data from tests QD-155-03 and QD-155-04, for which the simultaneity of detonation is uncertain, were analyzed in order to determine the effect of the non-simultaneous detonation. Figures 61 and 62 present comparisons of the fragment distribution and gamma distribution for the non-simultaneous tests and the simultaneous test QD-155-08. Both non-simultaneous distributions show significant deviation from the distributions of test QD-155-08. The non-simultaneous fragment distribution is heavier (i.e., greater average fragment weight) and the gamma distribution shows an increased number of more ballistically efficient (lower gamma) fragments.

These results tend to indicate that the far-field fragment density from non-simultaneous projectile detonations will be different than the density from simultaneous projectile detonations. However, the degree of non-simultaneity for these tests is unknown and may, or may not, be representative of actual conditions. Consequently, it is felt that until additional data are available the effect of non-simultaneous detonation cannot be adequately defined.

CONCLUSIONS AND RECOMMENDATIONS

The present study provides a methodology which can be used to determine the far-field fragment hazards produced by the simultaneous detonation of a pallet of 155-mm projectiles. However, a more accurate set of guidelines for quantity-distance standards can be realized through achieving a better understanding of how this information can be applied to other mass-detonating munitions and to large scale magazine detonations which are, in most cases, sympathetically triggered. The following is a summary of conclusions and recommendations for developing a more accurate set of guidelines for quantity-distance standards of mass-detonating munitions.

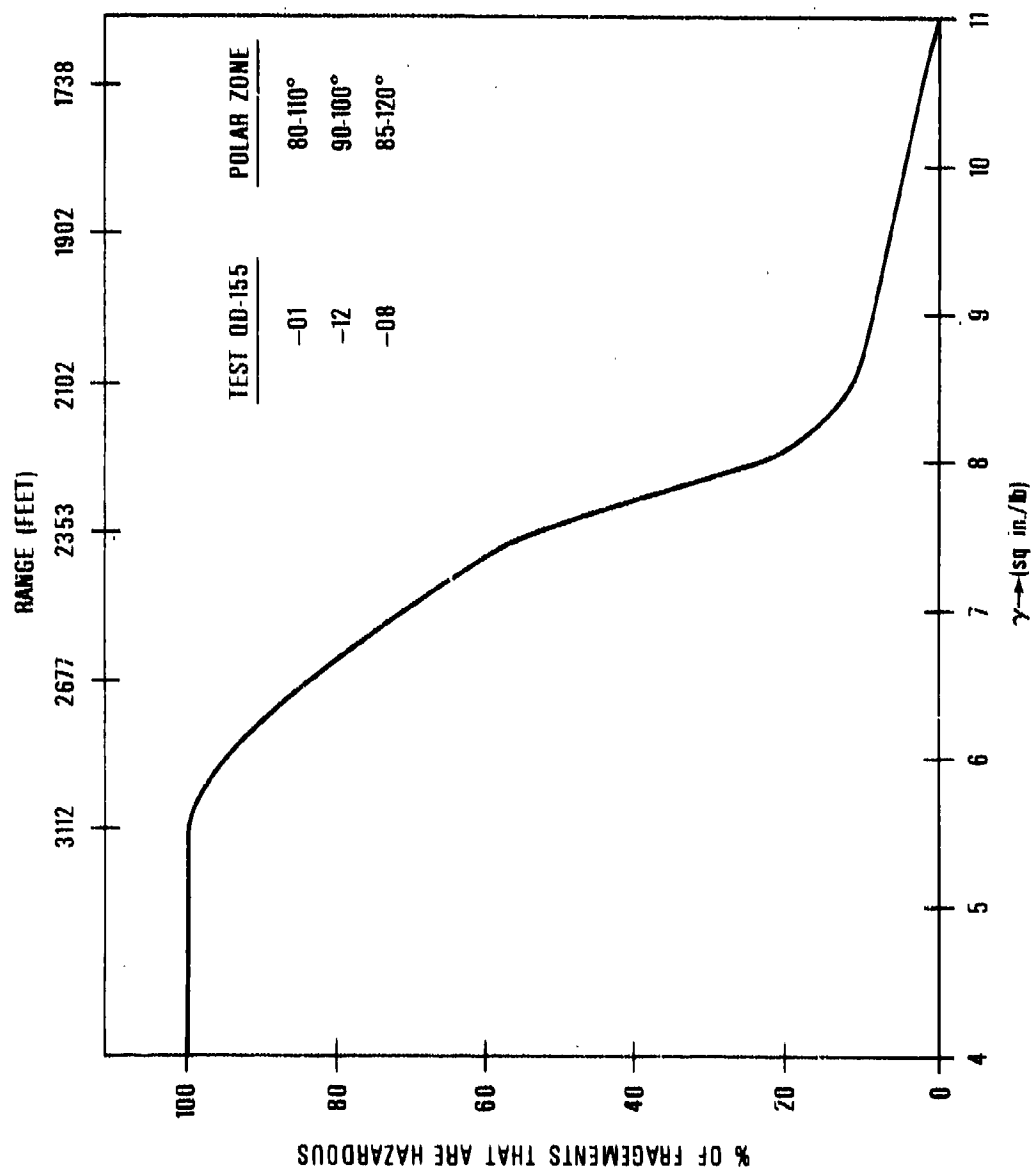


Figure 60. Percent of Hazardous Fragments Versus Range and Gamma

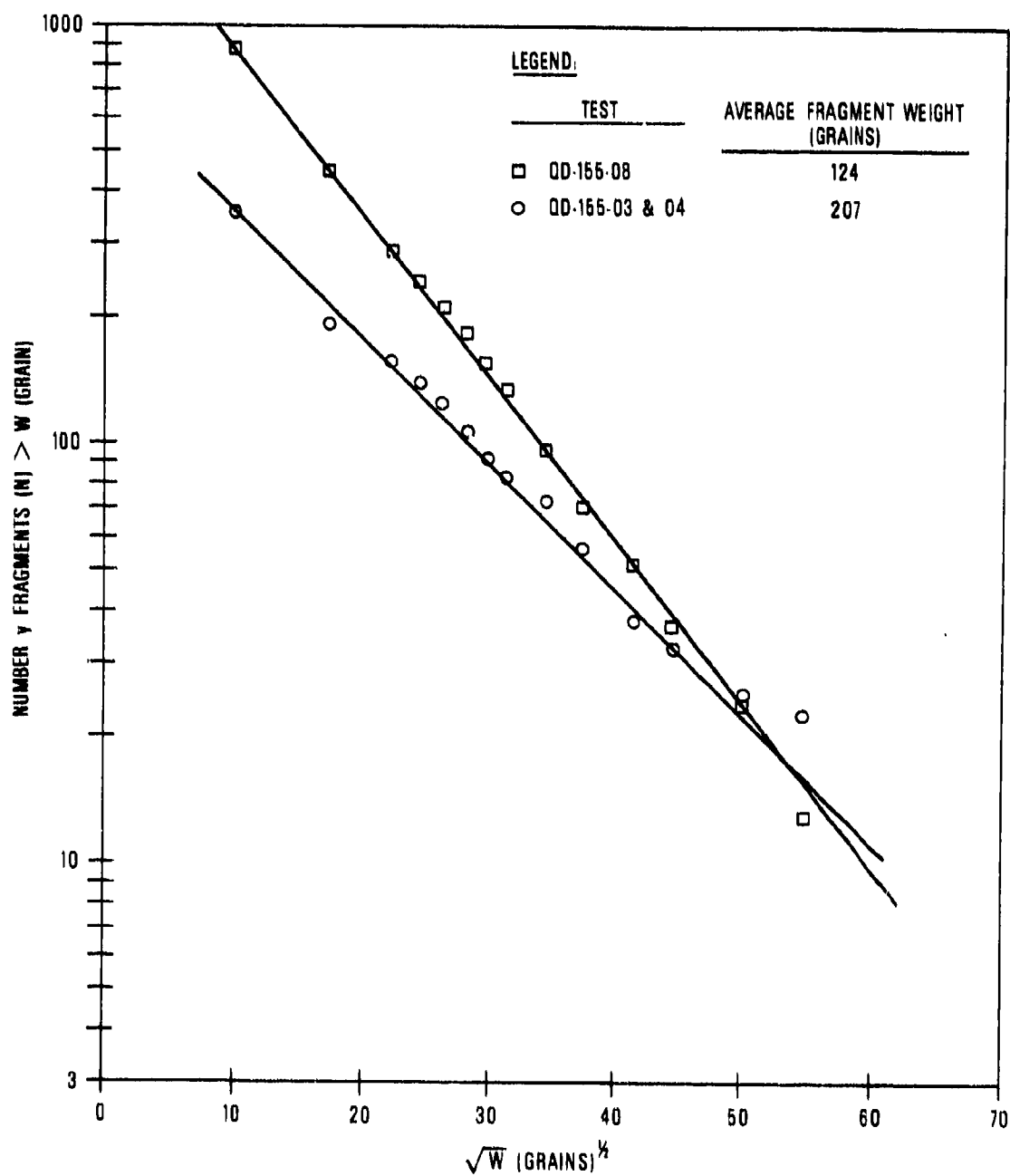


Figure 61. Mott Plots for Test QD-155-03, -04, and -08

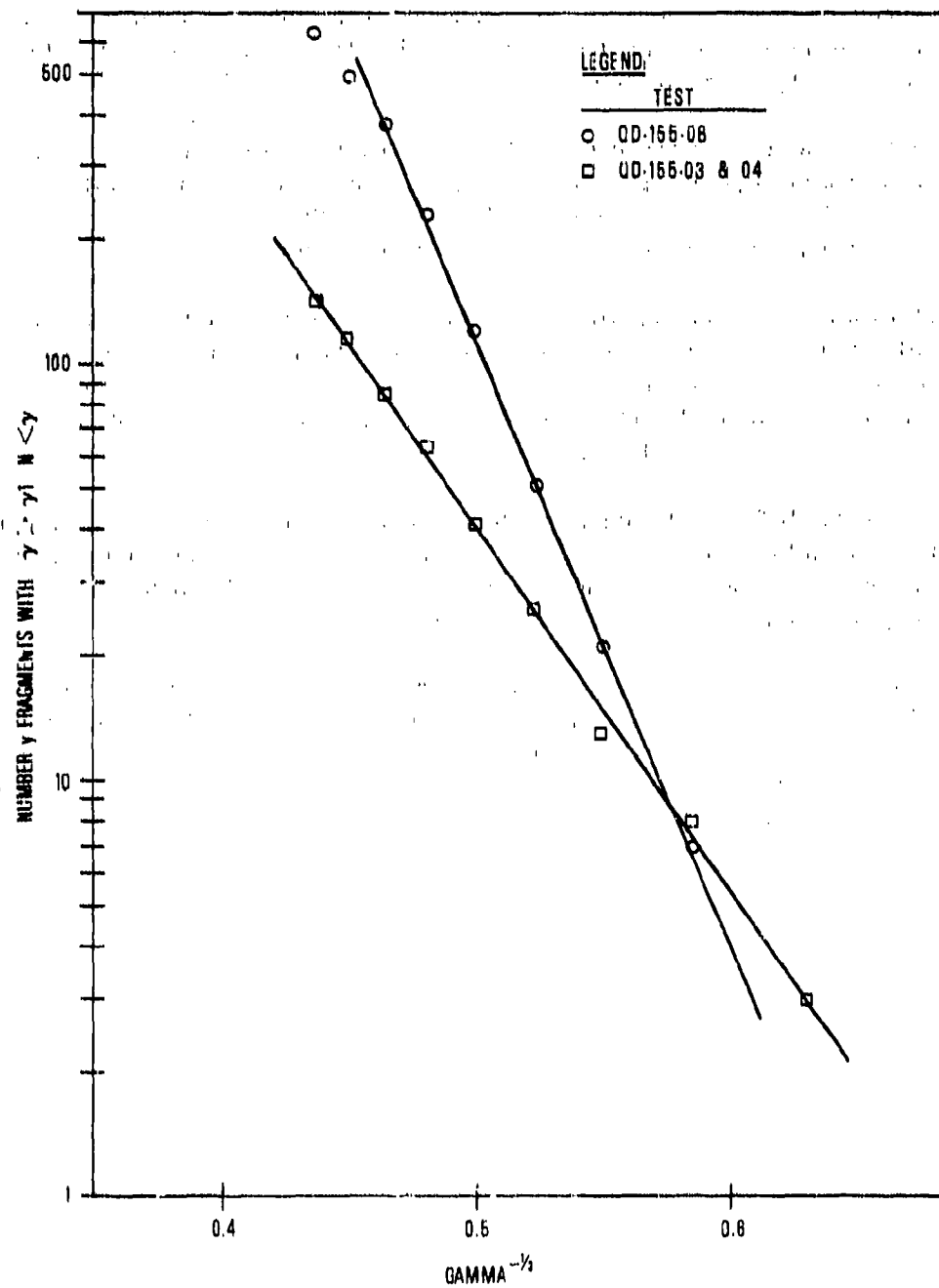


Figure 62. Relationship for the Number of Fragments Less Than Gamma Versus $\text{Gamma}^{-1/3}$ for Test QD-155-03, -04, and -08

1. The present fragment characterization model and formulations developed in this report are based solely on simultaneous detonations. It is recommended that a follow-on effort be initiated to determine if the experimental findings developed for a simultaneous detonation apply to the fragment hazards produced by the sympathetic detonation of 155-mm projectiles.

2. The arena test data clearly shows that the interaction areas possess a much greater potential for far-field fragment hazards than the areas outside of this region. It is recommended that a test series be conducted to determine the critical projectile spacing to alleviate the high velocity fragment concentrations and still maintain a high degree of efficiency for projectile storage.

3. Fragment aerodynamics is an important facet in the development of accurate quantity-distance standards. However, as previously discussed in this text, currently available drag curves for fragment velocities in the subsonic and transonic regions are inadequate for the development of a highly accurate trajectory routine. Therefore, it is recommended that further investigations be conducted to improve existing fragment drag curves.

4. It is not economically feasible to conduct a full scale test program to determine the far-field fragment hazards produced by each type of fragment producing munition. It is recommended that an analytical study and small-scale test program be conducted to determine the applicability of the 155-mm projectile formulation in this text to other mass-detonating munitions.

5. Comparisons of the multiple projectile arena data to the far-field fragment collection data of ESKIMO I indicate that quantity-distance data may possibly be obtained through small-scale testing (several pallets) instead of the more expensive large-scale detonations. It is recommended that a series of large-scale detonations be conducted to determine if the experimental formulations are applicable to large-scale tests.

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APPENDIX A

INDIVIDUAL STATIC ARENA TEST SHEETS

FRAGMENT HAZARD INVESTIGATION

Test Number:	QD-153-01
Item Tested:	M107 155mm projectile containing 15 lb of TNT explosive and equipped with a modified M564 Nose Fuze assembled with a Hercules Special Blasting Cap.
Number of Firings and Dates:	1 - 10 July 1975 2 - 11 July 1975
Number of Items per Firing:	1
Location of Test:	NSWC/DL - Experimental Explosive Area
Arena Configuration:	Polar Arena
	Fragment Recovery - 0°-180° Polar by 18° Azimuthal
	Fragment Velocities - 0°-180° Polar by 27° Azimuthal
Projectile Orientation:	One 155mm Projectile, Horizontal
Meteorology:	
10 July 1975	Barometric Pressure - 30.25 in. Hg Temperature - 94°F
11 July 1975	Barometric Pressure - 30.10 in. Hg Temperature - 96°F
Instrumentation:	Fragment Velocity - Five high speed motion picture cameras; black and white film.
Post Test Comments:	
10 July 1975	Largest concentration of fragments appear to be in Polar Zones 85°-105° No unusually large or excessive fragment penetrations in the Celotex or witness panels.
11 July 1975	Fragment observations for both firings same as above.

**FRAGMENT VELOCITIES AVERAGED
FOR THE THREE FIRINGS OF
TEST NO. QD-155-01**

Polar Zone (deg)	Avg Frag Velocity* (ft/s)
0- 5	2202.64
5- 10	2293.58
10- 15	2232.14
15- 20	2267.61
20- 25	**
25- 30	2252.25
30- 35	**
35- 40	2475.34
40- 45	2807.13
45- 50	2844.20
50- 55	3333.45
55- 60	3359.58
60- 65	3348.87
65- 70	3266.45
70- 75	3130.94
75- 80	3445.35
80- 85	3919.12
85- 90	4046.68
90- 95	4091.79
95-100	4169.31
100-105	3662.27
105-110	3531.06
110-115	3536.35
115-120	3172.70
120-125	3002.45
125-130	2481.56
130-135	2212.39
135-140	2249.01
140-145	2173.91
145-150	**
150-155	2905.10
155-160	2248.45
160-165	2173.91
165-170	2386.65
170-175	2534.86
175-180	2747.85

*Velocities recorded at 25.0 ft stand-off

**Instrumentation failure

**FRAGMENT WEIGHT AND NUMBER TOTALS COMBINED FOR
POLAR ZONES 0°-180° OF TEST NO. QD-155-01
(THREE FIRINGS)**

<u>Weight Group (Grains)</u>	<u>No. of Frgs</u>	<u>Total Weight</u>
.1- 100.0	364.0	7725.0
100.0- 300.0	79.0	14239.6
300.0- 500.0	35.0	12928.2
500.0- 600.0	12.0	6608.9
600.0- 700.0	11.0	7135.9
700.0- 800.0	9.0	6089.6
800.0- 900.0	5.0	4212.2
900.0-1000.0	6.0	5632.1
1000.0-1200.0	6.0	6439.4
1200.0-1400.0	5.0	5310.6
1400.0-1700.0	3.0	5984.1
1700.0-2000.0	2.0	3558.2
2000.0-2500.0	2.0	4706.1
2500.0-3000.0	1.0	2905.5
3000.0 +	1.0	3390.0

**FRAGMENT WEIGHT-PRESENTED AREA DATA
FOR TEST NO. QD-155-01**

Polar Zones 0°-180°

No. of Frags Selected for Measurements = 236

Frag Wt (Grains)	Presented Area (in. ²)		Average Area	Gamma (in. ² /lb)	Maximum Area	Gamma (in. ² /lb)
	Minimum Area	Gamma (in. ² /lb)				
1661.8	1.2490	5.26	1.4684	6.19	1.6690	7.03
2251.2	1.4063	4.37	1.9956	6.21	2.7563	8.57
1384.6	.9165	4.63	1.2403	6.27	1.5665	7.92
901.3	.5290	4.11	.8409	6.53	1.1490	8.92
2454.9	1.4045	4.00	2.3526	6.71	3.3945	9.68
1797.6	1.3050	5.08	1.7600	6.85	2.2350	8.70
838.4	.5520	4.61	.8226	6.87	1.0720	8.95
1311.3	1.0675	5.70	1.2975	6.93	1.4875	7.94
923.6	.7975	6.04	.9281	7.03	1.1975	9.08
777.5	.3075	2.77	.7869	7.08	1.3775	12.40
441.7	.1345	2.13	.4645	7.36	.7345	11.64
678.2	.3875	4.00	.7144	7.37	1.2175	12.57
3390.0	2.0145	4.16	3.6526	7.54	5.3545	11.06
424.1	.2370	3.91	.4582	7.56	.5870	9.69
1120.0	.5740	3.59	1.2115	7.57	1.9940	12.46
938.1	.8875	6.62	1.0188	7.60	1.1675	8.71
615.3	.5690	6.47	.6684	7.60	.7790	8.86
1652.6	.8720	3.69	1.8845	7.98	3.2720	13.86
808.7	.4735	4.10	.9254	8.01	1.5335	13.27
699.5	.4650	4.65	.9005	8.01	1.3450	13.46
698.4	.3345	3.35	.8076	8.09	1.2245	12.27
1018.1	.4525	3.11	1.1775	8.10	1.9825	13.63
808.5	.4650	4.03	.9362	8.11	1.7850	15.45
1031.3	.2070	1.41	1.2220	8.29	2.3270	15.79
2905.5	2.0425	4.92	3.5000	8.43	5.3925	12.99
203.8	.1770	4.70	.3289	8.73	.4970	13.19
646.9	.7023	7.60	.8197	8.87	.9423	10.20
557.7	.2280	2.86	.7317	9.18	1.1480	14.41
1192.8	1.0950	6.43	1.5888	9.32	2.0150	11.83
883.8	.3980	3.15	1.1786	9.34	1.8480	14.64
405.5	.1615	2.79	.5427	9.37	.9215	15.91
570.2	.5815	7.14	.7709	9.46	.8915	10.94
627.4	.5668	6.32	.8586	9.58	1.1068	12.35
1275.2	1.0270	5.64	1.7489	9.60	3.0770	16.89
1339.5	.9130	4.77	1.8543	9.69	3.0830	16.11
633.7	.4765	5.26	.8790	9.71	1.4165	15.65
722.4	.8675	8.41	1.0069	9.76	1.1975	11.60
872.8	.6865	5.51	1.2171	9.76	1.8365	14.73
983.6	.6415	4.57	1.3859	9.86	2.2615	16.09
566.2	.3235	4.00	.8041	9.94	1.4035	17.35
435.4	.3515	5.65	.6227	10.01	.9015	14.49
1036.5	1.1780	7.96	1.4836	10.02	1.8280	12.35
607.3	.4575	5.27	.8875	10.23	1.5275	17.61
501.7	.3675	5.13	.7337	10.24	1.1375	15.87
321.5	.2385	5.19	.4735	10.31	.7885	17.17
546.3	.4190	5.37	.8152	10.45	1.4590	18.69
1434.3	1.2015	5.86	2.1553	10.52	3.4515	16.84
327.6	.3330	7.12	.4961	10.60	.6830	14.59
539.2	.5405	7.02	.8310	10.79	1.2705	16.49
708.8	.3618	3.17	1.2336	10.81	2.0718	18.16
457.8	.4375	6.69	.7112	10.88	1.0675	16.32

**FRAGMENT WEIGHT-PRESENTED AREA DATA
FOR TEST NO. QD-155-01**

Polar Zones 0°-180°

No. of Frags Selected for Measurements = 236

Frag Wt (Grains)	Presented Area (in. ²)		Average Area	Gamma (in. ² /lb)	Maximum Area	Gamma (in. ² /lb)
	Minimum Area	Gamma (in. ² /lb)				
697.3	.4365	4.38	1.0834	10.88	1.6765	16.83
230.4	.2040	6.20	.3584	10.89	.4940	15.01
170.6	.0470	1.93	.2658	10.90	.4870	19.98
373.4	.2790	5.23	.5834	10.94	.9390	17.60
755.9	.5950	5.51	1.1844	10.97	1.9450	18.01
743.6	.4510	4.25	1.1673	10.99	1.8010	16.95
767.0	.5155	4.70	1.2180	11.12	1.9655	17.94
119.3	.0395	2.32	.1914	11.23	.3595	21.09
309.3	.1015	2.30	.5009	11.34	.8415	19.04
270.0	.3000	7.78	.4444	11.52	.6500	16.85
265.8	.2075	5.46	.4375	11.52	.6075	16.00
368.8	.2290	4.35	.6071	11.52	.8990	17.06
467.7	.4575	6.85	.7700	11.52	1.2275	18.37
323.2	.2305	4.99	.5324	11.53	.8305	17.99
794.5	.7165	6.31	1.3178	11.61	1.9365	17.06
983.3	.8945	6.37	1.6314	11.61	2.4045	17.12
218.7	.2655	8.50	.3649	11.68	.5055	16.18
260.5	.2330	6.26	.4355	11.70	.6730	18.08
316.4	.1645	3.64	.5295	11.71	.8245	18.24
1235.4	1.1405	6.46	2.0811	11.79	3.1605	17.91
571.2	.4510	5.53	.9679	11.86	1.6310	19.99
357.8	.3045	5.96	.6095	11.92	.9745	19.07
144.2	.0540	2.62	.2471	12.00	.5040	24.47
388.3	.4075	7.35	.6769	12.20	1.0475	18.88
557.5	.3950	4.96	.9744	12.23	1.5950	20.03
372.4	.5870	11.03	.6526	12.27	.7470	14.04
396.8	.4745	8.37	.6957	12.27	.9245	16.31
324.0	.3300	7.13	.5725	12.37	.8600	18.58
340.2	.4215	8.67	.6027	12.40	.7515	15.46
498.9	.5535	7.77	.8881	12.46	1.3435	18.85
608.0	.2325	2.68	1.0881	12.53	1.9025	21.90
254.2	.1530	4.21	.4555	12.54	.8230	22.66
130.7	.0955	5.11	.2343	12.55	.4655	24.93
342.1	.3745	7.66	.6145	12.57	.9745	19.94
623.9	.6250	7.01	1.1231	12.60	1.7950	20.14
307.2	.3600	8.20	.5537	12.62	.8000	18.23
117.6	.0755	4.49	.2124	12.64	.4055	24.14
341.9	.5440	11.14	.6190	12.67	.6840	14.00
372.2	.3445	6.48	.3764	12.72	1.0945	20.58
201.9	.1230	4.26	.3674	12.74	.6330	21.95
552.2	.5765	7.31	1.0071	12.77	1.4865	18.84
273.3	.2885	7.39	.4991	12.78	.7585	19.43
318.9	.3815	8.37	.5865	12.87	.8915	19.57
902.2	.7730	6.00	1.6786	13.02	2.7430	21.28
368.5	.3145	5.97	.6857	13.03	.9045	17.18
188.1	.1420	5.28	.3514	13.08	.5040	18.76
271.8	.1285	3.31	.5079	13.08	.8285	21.34
289.2	.2815	6.81	.5434	13.15	.8115	19.64
729.9	.9040	8.67	1.3728	13.17	2.0240	19.41
129.5	.1095	5.92	.2439	13.18	.4095	22.14
520.4	.6305	8.48	.9811	13.20	1.4605	19.65
298.5	.2490	5.84	.5640	13.23	.8590	20.14
303.0	.2853	6.59	.5752	13.29	.9153	21.14

**FRAGMENT WEIGHT-PRESENTED AREA DATA
FOR TEST NO. QD-155-01**

Polar Zones 0°-180°

No. of Frags Selected for Measurements = 236

<u>Frag Wt (Grains)</u>	<u>Minimum Area</u>	<u>Presented Area (in.²) Gamma (in.²/lb)</u>	<u>Average Area</u>	<u>Gamma (in.²/lb)</u>	<u>Maximum Area</u>	<u>Gamma (in.²/lb)</u>
538.1	.6890	8.96	1.0334	13.44	1.3590	17.68
108.1	.0910	5.89	.2079	13.46	.3510	22.73
240.5	.2600	7.57	.4631	13.48	.7200	20.96
302.1	.2890	6.70	.5846	13.55	.9490	21.99
235.2	.2885	8.59	.4554	13.55	.6385	19.00
1760.6	1.9295	7.67	3.4126	13.57	5.1295	20.39
326.4	.2260	4.85	.6385	13.69	1.1260	24.15
193.1	.1915	6.94	.3821	13.85	.6315	22.89
259.6	.0830	2.24	.5168	13.93	.8330	22.46
250.2	.2675	7.48	.4981	13.94	.7275	20.35
206.0	.2410	8.19	.4129	14.03	.5810	19.74
104.8	.1365	9.12	.2103	14.04	.2965	19.80
280.0	.3315	8.29	.5621	14.05	.8415	21.04
424.1	.3905	6.45	.8530	14.08	1.4505	23.94
245.2	.3185	9.09	.4948	14.12	.6485	18.51
282.8	.2330	5.77	.5717	14.15	.9030	22.35
273.6	.2483	6.35	.5582	14.28	.8683	22.21
361.0	.3560	6.90	.7372	14.30	1.1160	21.64
146.0	.1030	4.94	.3005	14.41	.4830	23.16
588.2	.7830	9.34	1.2113	14.41	1.7450	20.77
239.1	.1330	3.89	.4949	14.49	.7430	21.75
249.3	.2930	8.23	.5199	14.60	.7830	21.99
105.7	.1580	10.46	.2205	14.60	.3080	20.40
131.2	.1595	8.51	.2745	14.65	.3895	20.78
168.6	.1800	7.47	.3569	14.82	.6200	25.74
181.8	.1770	6.82	.3895	15.00	.5470	21.06
154.3	.1655	7.51	.3311	15.02	.4755	21.57
123.3	.0870	4.94	.2658	15.09	.4570	25.94
1040.7	1.7255	11.61	2.2805	15.34	2.5455	17.12
230.0	.2170	6.60	.5126	15.60	.9070	27.60
103.5	.1155	7.81	.2311	15.63	.4355	29.45
179.8	.2848	11.09	.4129	16.07	.5448	21.21
194.6	.1255	4.51	.4486	16.14	.7255	26.10
146.7	.1370	6.54	.3433	16.38	.6470	30.87
199.3	.2530	8.89	.4705	16.53	.6730	23.64
167.7	.2085	8.70	.3960	16.53	.6185	25.82
117.2	.1440	8.60	.2796	16.70	.3940	23.53
170.5	.2255	9.26	.4074	16.73	.5955	24.45
132.5	.2965	15.66	.3184	16.82	.3365	17.78
460.0	.7550	11.49	1.1119	16.92	1.4950	22.75
109.5	.1410	9.01	.2648	16.92	.4110	26.27
135.5	.1200	6.20	.3281	16.95	.5000	25.83
194.5	.3240	11.66	.4721	16.99	.6540	23.54
216.1	.4685	15.18	.5366	17.38	.6285	20.36
316.4	.4760	10.18	.7879	17.43	1.1360	25.13
185.7	.2700	13.14	.4644	17.50	.6500	24.50
116.9	.2193	11.34	.2926	17.52	.3695	22.13
231.7	.3755	7.33	.5805	17.54	.7855	23.73
163.7	.1715	6.76	.4121	17.62	.6415	27.43
131.6	.1270	8.20	.3333	17.73	.5570	29.63
126.8	.1485		.3285	18.13	.5085	28.07

**FRAGMENT WEIGHT-PRESENTED AREA DATA
FOR TEST NO. QD-155-01**

Polar Zones 0°-180°

No. of Frags Selected for Measurements = 236

Frag Wt (Grains)	Minimum Area	Presented Area (in. ²)		Average Area	Gamma (in. ² /lb)	Maximum Area	Gamma (in. ² /lb)
		Gamma (in. ² /lb)	Gamma (in. ² /lb)				
122.1	.1800	10.32	.3175	18.20	.5000	28.67	
250.7	.3460	9.66	.6597	18.42	1.0960	30.60	
157.4	.1800	8.01	.4181	18.60	.6700	29.80	
186.5	.2015	7.56	.4996	18.75	.7915	29.71	
152.3	.2755	12.66	.4105	18.87	.5955	27.37	
132.1	.1725	9.14	.3613	19.14	.5325	28.22	
159.4	.2655	11.66	.4461	19.59	.6655	29.23	
319.6	.6220	13.62	.9064	19.85	1.1920	26.11	
164.8	.3485	14.80	.4754	20.19	.7185	30.52	
138.1	.1900	9.63	.4013	20.34	.6000	30.41	
414.0	.9965	16.85	1.2290	20.78	1.4765	24.96	
119.5	.2655	15.55	.3711	21.74	.4755	27.85	
124.9	.3325	18.63	.3894	21.82	.4525	25.36	
104.6	.1740	11.64	.3265	21.85	.4440	29.71	
114.8	.2595	15.82	.3689	22.49	.5295	32.29	
108.9	.2840	18.26	.4015	25.81	.5340	34.33	
156.7	.5095	22.76	.6832	30.52	.9395	41.97	
123.0	.1745	9.93	.5489	31.24	1.1145	63.43	
117.4	.4340	25.88	.5915	35.27	.7340	43.76	
168.8	.6365	26.40	1.2615	52.31	2.1465	89.01	
107.3	.5520	36.01	1.0001	65.25	1.5420	100.60	

FRAGMENT HAZARD INVESTIGATION

Test Number: QD-155-02

Item Tested: M107 155mm Projectile containing 15 lb of TNT explosive and equipped with a modified M564 Nose Fuze assembled with a Hercules Special Blasting Cap.

Number of Firings and Dates: 1 - 11 August 1975
1 - 12 August 1975
1 - 13 August 1975

Number of Items per Firing: 2

Location of Test: NSWC/DL - Experimental Explosive Area

Arena Configuration: Polar Arena

Fragment Recovery -- 0°-180° Polar by 18° Azimuthal

Fragment Velocities -- 0°-180° Polar by 27° Azimuthal

Cluster Configuration: Two projectiles oriented horizontally, side by side, with the projectile centerlines parallel and seven inches apart.

Meteorology:

11 August 1975	Barometric Pressure	-- 30.12 in. Hg
	Temperature	-- 80°F
12 August 1975	Barometric Pressure	-- 29.58 in. Hg
	Temperature	-- 75°F
13 August 1975	Barometric Pressure	-- 31.01 in. Hg
	Temperature	-- 78°F

Instrumentation: Fragment Velocity -- Five high speed motion picture cameras; black and white film.

Post Test Comments: Largest concentration of fragments appear to be in polar zones 90°-105°.

Fragment penetrations in the Celotex and witness panels indicate that the fragment density as compared to the first test (QD-155-01), has increased.

**FRAGMENT VELOCITIES AVERAGED
FOR THE THREE FIRINGS OF
TEST NO. QD-155-02**

Polar Zone (deg)	Avg Frag Velocity* (ft/s)
0- 5	1274.58
5- 10	1748.76
10- 15	1659.79
15- 20	1211.27
20- 25	**
25- 30	1061.57
30- 35	1355.37
35- 40	1252.32
40- 45	1242.28
45- 50	1305.69
50- 55	1056.73
55- 60	2133.97
60- 65	2636.51
65- 70	1373.67
70- 75	3581.22
75- 80	3911.67
80- 85	4066.06
85- 90	4655.44
90- 95	4451.28
95-100	4486.28
100-105	4058.58
105-110	3822.86
110-115	2631.58
115-120	**
120-125	**
125-130	**
130-135	909.59
135-140	**
140-145	915.01
145-150	**
150-155	874.35
155-160	**
160-165	1086.64
165-170	2191.87
170-175	2438.72
175-180	2682.81

*Velocities recorded at 25.0 ft stand-off
**instrumentation failure

**FRAGMENT WEIGHT AND NUMBER TOTALS COMBINED FOR
POLAR ZONES 0°-180° OF TEST NO. QD-155-02
(THREE FIRINGS)**

<u>Weight Group (Grains)</u>	<u>No. of Frgs</u>	<u>Total Weight</u>
.1- 100.0	650.0	11491.9
100.0- 300.0	110.0	19564.7
300.0- 500.0	49.0	19196.8
500.0- 600.0	12.0	6569.1
600.0- 700.0	15.0	9835.7
700.0- 800.0	10.0	7492.6
800.0- 900.0	11.0	9162.2
900.0-1000.0	8.0	7627.5
1000.0-1200.0	19.0	20593.7
1200.0-1400.0	5.0	6671.1
1400.0-1700.0	9.0	13945.8
1700.0-2000.0	4.0	7590.0
2000.0-2500.0	4.0	9020.4
2500.0-3000.0	1.0	2530.5
3000.0 +	2.0	15024.6

**FRAGMENT WEIGHT-PRESENTED AREA DATA
FOR TEST NO. QD-155-02**

Polar Zones 0°-180°

No. of Frags Selected for Measurements = 236

Frag Wt (Grains)	Presented Area (in. ²)		Average Area	Gamma (in. ² /lb)	Maximum Area	Gamma (in. ² /lb)
	Minimum Area	Gamma (in. ² /lb)				
11927.8	1.8600	1.09	7.3844	4.33	15.4800	9.08
3096.8	1.9355	4.38	2.4868	5.62	2.9755	6.73
2212.7	1.4440	4.57	1.9565	6.19	2.5240	7.98
2329.9	1.6395	4.93	2.1045	6.32	2.5295	7.60
1752.8	1.3450	5.37	1.6706	6.67	1.9850	7.93
1975.0	1.4525	5.15	1.9075	6.76	2.3725	8.41
1598.5	1.4120	6.18	1.5733	6.89	1.9020	8.33
2042.9	1.5040	5.15	2.0196	6.92	2.5940	8.89
1901.0	1.4600	5.38	1.9338	7.12	2.7600	10.16
1600.1	1.3635	5.96	1.6429	7.19	1.9735	8.63
1531.4	1.2410	5.67	1.5916	7.28	1.9810	9.06
1514.9	1.1650	5.38	1.5756	7.28	1.8650	8.62
2434.9	.8595	2.47	2.5401	7.30	4.0595	11.67
1572.3	1.2865	5.73	1.6446	7.32	2.0465	9.11
1569.4	1.4265	6.36	1.6484	7.35	1.9265	8.59
1961.2	.7995	2.85	2.0701	7.39	3.6495	13.03
822.1	.4735	4.03	.8760	7.46	1.3835	11.78
1515.0	1.2795	5.91	1.6333	7.55	1.9195	8.87
1617.1	1.3125	5.68	1.7788	7.70	2.3525	10.18
1080.7	.9820	6.36	1.2208	7.91	1.5220	9.86
1161.1	1.0135	6.11	1.3198	7.96	1.5135	9.12
1084.3	.7025	4.54	1.2463	8.05	1.9825	12.80
742.9	.5045	4.75	.8570	8.08	1.1045	10.41
1257.8	.7785	4.33	1.4560	8.10	2.1585	12.01
1159.5	1.0035	6.06	1.3585	8.20	1.6735	10.10
1427.1	1.2110	5.94	1.6754	8.22	2.0110	9.86

**FRAGMENT WEIGHT-PRESENTED AREA DATA
FOR TEST NO. QD-155-02**

Polar Zones 0°-180°

No. of Frags Selected for Measurements = 236

Frag Wt (Grains)	Presented Area (in. ²)		Average Area	Gamma (in. ² /lb)	Maximum Area	Gamma (in. ² /lb)
	Minimum Area	Gamma (in. ² /lb)				
1340.8	1.2865	6.72	1.5790	8.24	1.9965	10.42
1119.2	.9180	5.74	1.3224	8.27	1.9980	12.50
2530.5	1.5200	4.20	3.0031	8.31	5.0300	13.91
821.6	.5720	4.87	.9764	8.32	1.4920	12.71
942.0	.6775	5.03	1.1313	8.41	1.7875	13.28
1307.4	.6480	3.47	1.5718	8.42	2.4280	13.00
763.1	.5575	5.11	.9181	8.42	1.2775	11.72
265.5	.1630	4.30	.3249	8.57	.5830	15.37
1022.0	.9105	6.24	1.2599	8.63	1.5305	10.48
1057.3	.9705	6.43	1.3049	8.64	1.6505	10.93
1030.5	.5685	3.86	1.2741	8.65	1.9385	13.17
1389.2	1.2295	6.20	1.7339	8.74	2.2095	11.13
1069.1	.7055	4.62	1.3368	8.75	2.1355	13.98
942.8	.7065	5.25	1.1803	8.76	1.5665	11.63
765.9	.6305	5.76	.9655	8.82	1.2605	11.52
1049.2	.7140	4.76	1.3478	8.99	1.9640	13.10
936.8	.5910	4.42	1.2241	9.15	1.5810	11.81
741.7	.5410	5.11	.9722	9.18	1.3910	13.13
900.0	.7780	6.05	1.1836	9.21	1.6680	12.97
824.0	.8120	6.90	1.0920	9.28	1.3220	11.23
656.1	.5583	5.96	.8714	9.30	1.2483	13.32
814.0	.7250	6.23	1.0850	9.33	1.5150	13.03
862.5	.8260	6.70	1.1648	9.45	1.3560	11.01
603.0	.4600	5.34	.8150	9.46	1.2200	14.16
805.4	.6595	5.73	1.0933	9.50	1.7995	15.64
586.9	.3645	4.35	.7970	9.51	1.0145	12.10

**FRAGMENT WEIGHT-PRESENTED AREA DATA
FOR TEST NO. QD-155-02**

Polar Zones 0°-180°

No. of Frags Selected for Measurements = 236

Frag Wt (Grains)	Minimum Area	Presented Area (in. ²)		Average Area	Gamma (in. ² /lb)	Maximum Area	Gamma (in. ² /lb)
		Gamma (in. ² /lb)	Gamma (in. ² /lb)				
1385.4	.9175	4.64	1.8825	9.51	2.6475	13.38	
1172.5	.7245	4.33	1.5995	9.55	2.3345	13.94	
814.8	.6050	5.20	1.1138	9.57	1.7150	14.73	
981.8	.4655	3.32	1.3436	9.58	2.0055	14.30	
1120.7	.7455	4.66	1.5349	9.59	2.3355	14.59	
870.9	.5880	4.73	1.1930	9.59	1.9080	15.34	
1071.6	.5660	3.70	1.4735	9.63	2.5960	16.96	
540.8	.4345	5.62	.7451	9.64	1.0145	13.13	
860.0	.5950	4.84	1.1850	9.65	1.6550	13.47	
667.0	.7045	7.39	.9207	9.66	1.1745	12.33	
629.4	.4630	5.15	.8736	9.72	1.0730	11.93	
996.0	.6855	4.82	1.4093	9.90	2.3355	16.41	
627.3	.4620	5.16	.8945	9.98	1.3420	14.98	
692.7	.5865	5.93	.9884	9.99	1.4765	14.92	
664.6	.5350	5.63	.9500	10.01	1.3950	14.69	
687.2	.6335	6.45	.9841	10.02	1.4535	14.81	
725.6	.5450	5.26	1.0419	10.05	1.6050	15.48	
1172.2	1.1200	6.69	1.6838	10.05	2.3800	14.21	
693.9	.7575	7.64	1.0100	10.19	1.2175	12.28	
820.0	.9775	8.34	1.1981	10.23	1.4175	12.10	
671.8	.6320	6.59	1.0133	10.56	1.4420	15.03	
987.8	.8085	5.73	1.4910	10.56	2.1185	15.01	
688.1	.5620	5.72	1.0401	10.58	1.6620	16.91	
502.0	.4685	6.53	.7635	10.65	.9985	13.92	
626.4	.2810	3.14	.9535	10.66	1.5710	17.56	
718.6	.4525	4.41	1.0975	10.69	1.8525	18.05	

**FRAGMENT WEIGHT-PRESENTED AREA DATA
FOR TEST NO. QD-155-02**

Polar Zones 0°-180°

No. of Frags Selected for Measurements = 236

Frag Wt (Grains)	Minimum Area	Presented Area (in. ²)		Average Area	Gamma (in. ² /lb)	Maximum Area	Gamma (in. ² /lb)
		Gamma (in. ² /lb)					
684.0	.5325	5.45	1.0469	10.71	1.6425	16.81	
486.1	.4530	6.52	.7455	10.74	1.1330	16.32	
185.1	.1770	6.69	.2864	10.83	.4170	15.77	
846.9	.6140	5.07	1.3228	10.93	1.9540	16.15	
529.7	.5320	7.03	.8289	10.95	1.1720	15.49	
565.3	.5245	6.49	.8895	11.01	1.3545	16.77	
449.2	.3530	5.50	.7074	11.02	1.0230	15.94	
485.5	.5615	8.10	.7646	11.02	.9515	13.72	
461.1	.4430	6.73	.7274	11.04	1.0930	16.59	
235.3	.2285	6.80	.3716	11.06	.5485	16.32	
322.9	.3663	7.94	.5169	11.21	.6763	14.66	
554.0	.7375	9.32	.8919	11.27	1.0975	13.87	
351.9	.3130	6.23	.5674	11.29	.7730	15.38	
384.9	.3515	6.39	.6215	11.30	.9415	17.12	
797.7	.6455	5.66	1.3024	11.43	2.3155	20.32	
324.1	.3470	7.49	.5295	11.44	.6570	14.19	
641.7	.6235	6.80	1.0485	11.44	1.6335	17.82	
720.8	.5340	5.19	1.1796	11.46	1.7640	17.13	
734.8	.6425	6.12	1.2056	11.49	1.8425	17.55	
781.5	.6310	5.65	1.2823	11.49	1.8910	16.94	
572.3	.5320	6.51	.9439	11.54	1.3920	17.03	
542.4	.5790	7.47	.8959	11.56	1.3390	17.28	
514.0	.4820	6.56	.8532	11.62	1.1920	16.23	
187.3	.1825	6.82	.3113	11.63	.4425	16.54	
421.8	.3905	6.48	.7117	11.81	1.1105	18.43	
272.9	.3270	8.39	.4626	11.87	.6170	15.83	

**FRAGMENT WEIGHT-PRESENTED AREA DATA
FOR TEST NO. QD-155-02**

Polar Zones 0°-180°

No. of Frags Selected for Measurements = 236

Frag Wt (Grains)	Minimum Area	Presented Area (in. ²)		Average Area	Gamma (in. ² /lb)	Maximum Area	Gamma (in. ² /lb)
		Gamma (in. ² /lb)					
399.3	.4305	7.55	.6811	11.94	1.0805	18.94	
237.0	.2615	7.72	.4046	11.95	.5615	16.58	
264.7	.2755	7.29	.4530	11.98	.6755	17.86	
536.4	.6660	8.69	.9197	12.00	1.2460	16.26	
468.6	.4483	6.70	.8045	12.02	1.2983	19.39	
417.2	.3835	6.43	.7172	12.03	1.1935	20.03	
426.5	.4415	7.25	.7359	12.08	.9815	16.11	
592.9	.4665	5.51	1.0259	12.11	1.4965	17.67	
429.0	.3945	6.44	.7457	12.17	1.1245	18.35	
928.2	.7245	5.46	1.6258	12.26	2.3845	17.98	
414.5	.3590	6.06	.7277	12.29	1.1390	19.24	
602.5	.5243	6.09	1.0636	12.36	1.5343	17.83	
388.9	.3705	6.67	.6917	12.45	1.1105	19.99	
436.5	.3820	6.13	.7776	12.47	1.2320	19.76	
391.2	.3245	5.81	.6976	12.48	1.0845	19.41	
431.7	.4005	6.49	.7755	12.57	1.2305	19.95	
435.1	.4835	7.78	.7872	12.67	1.1635	18.72	
272.6	.3070	7.88	.4970	12.76	.7870	20.21	
395.5	.4245	7.51	.7301	12.92	1.0945	19.37	
382.1	.2935	5.38	.7147	13.09	1.1835	21.68	
123.8	.1395	7.89	.2326	13.15	.3095	17.50	
343.0	.3190	6.51	.6565	13.40	1.0590	21.61	
428.9	.3635	5.93	.8229	13.43	1.2835	20.95	
417.5	.4050	6.79	.8019	13.44	1.2050	20.20	
320.9	.4015	8.76	.6184	13.49	.7915	17.27	
532.4	.5665	7.45	1.0296	13.54	1.8065	23.75	

FRAGMENT WEIGHT-PRESENTED AREA DATA
FOR TEST NO. QD-155-02

Polar Zones 0°-180°

No. of Frags Selected for Measurements = 236

<u>Frag Wt (Grains)</u>	<u>Minimum Area</u>	<u>Presented Area (in.²) Gamma (in.²/lb)</u>	<u>Average Area</u>	<u>Gamma (in.²/lb)</u>	<u>Maximum Area</u>	<u>Gamma (in.²/lb)</u>
456.9	.4365	6.69	.8846	13.55	1.3965	21.40
199.6	.2100	7.36	.3919	13.74	.6500	22.80
328.6	.2738	5.83	.6494	13.83	1.0038	21.38
289.2	.3260	7.89	.5741	13.90	.8760	21.20
227.0	.1700	5.24	.4544	14.01	.6100	18.81
317.2	.3220	7.11	.6351	14.02	1.1120	24.54
1117.3	1.3995	8.77	2.2464	14.07	3.4495	21.61
314.2	.3375	7.52	.6319	14.08	.9275	20.66
386.9	.3790	6.86	.7809	14.13	1.3090	23.68
264.0	.3045	8.07	.5345	14.17	.7845	20.80
176.7	.1640	6.50	.3621	14.35	.5140	20.36
193.4	.2170	7.85	.3989	14.44	.5570	20.16
238.9	.2875	8.42	.4944	14.49	.7475	21.90
243.7	.2800	8.04	.5056	14.52	.7400	21.26
186.6	.3080	11.55	.3874	14.53	.4680	17.56
164.9	.1985	8.43	.3454	14.66	.5585	23.71
353.3	.4375	8.67	.7412	14.69	1.0575	20.95
231.8	.3370	10.18	.4876	14.73	.6270	18.93
176.3	.2570	10.20	.3714	14.75	.5170	20.53
166.1	.2370	9.99	.3508	14.78	.4970	20.95
286.3	.3505	8.57	.6105	14.93	.8605	21.04
155.1	.2080	9.39	.3311	14.94	.4780	21.57
128.6	.1295	7.05	.2764	15.04	.3995	21.75
205.1	.2300	7.85	.4412	15.06	.7200	24.57
409.7	.5420	9.26	.8889	15.19	1.3120	22.42
181.9	.2000	7.70	.3981	15.32	.5600	21.55

**FRAGMENT WEIGHT-PRESENTED AREA DATA
FOR TEST NO. QD-155-02**

Polar Zones 0°-180°

No. of Frags Selected for Measurements = 236

<u>Frag Wt (Grains)</u>	<u>Minimum Area</u>	<u>Presented Area (in.²) Gamma (in.²/lb)</u>	<u>Average Area</u>	<u>Gamma (in.²/lb)</u>	<u>Maximum Area</u>	<u>Gamma (in.²/lb)</u>
310.1	.3245	7.33	.6795	15.34	1.1545	26.06
374.5	.4050	7.57	.8219	15.36	1.2650	23.64
373.3	.4335	8.13	.8210	15.40	1.3435	25.19
284.5	.4323	10.64	.6272	15.43	.7923	19.49
185.9	.2025	7.63	.4100	15.44	.6125	23.06
170.1	.1470	6.05	.3758	15.46	.6070	24.98
187.7	.2600	9.70	.4156	15.50	.6800	25.36
1034.1	1.8700	12.66	2.2925	15.52	2.4800	16.79
325.6	.3238	6.96	.7244	15.57	1.0838	23.30
1030.8	1.8285	12.42	2.2991	15.61	2.5183	17.10
1024.2	1.9225	13.14	2.2850	15.62	2.5325	17.31
200.7	.2245	7.83	.4495	15.68	.6645	23.18
183.1	.2355	9.00	.4124	15.77	.5855	22.38
245.1	.2175	6.21	.5537	15.81	.7475	21.35
161.9	.2440	10.55	.3665	15.85	.4840	20.93
298.0	.3635	8.54	.6767	15.89	.9735	22.87
179.1	.2700	10.55	.4081	15.95	.5300	20.71
1017.4	1.8900	13.00	2.3306	16.04	2.5700	17.68
293.4	.4815	11.49	.6771	16.15	.8015	19.12
140.1	.2270	11.34	.3258	16.28	.4670	23.33
248.2	.3245	9.15	.5782	16.31	.8945	25.23
275.1	.2790	7.10	.6415	16.32	.8690	22.11
148.6	.1885	8.88	.3466	16.33	.6085	28.66
189.6	.2730	10.08	.4499	16.61	.7030	25.95
148.4	.2625	12.38	.3525	16.63	.4125	19.46
185.1	.3263	12.34	.4400	16.64	.5463	20.66

**FRAGMENT WEIGHT-PRESENTED AREA DATA
FOR TEST NO. QD-155-02**

Polar Zones 0°-180°

No. of Frags Selected for Measurements = 236

Frag Wt (Grains)	Presented Area (in. ²)		Average Area	Gamma (in. ² /lb)	Maximum Area	Gamma (in. ² /lb)
	Minimum Area	Gamma (in. ² /lb)				
144.4	.2240	10.86	.3453	16.74	.4840	23.46
150.3	.1885	8.78	.3598	16.75	.5585	26.01
113.0	.1825	11.31	.2706	16.76	.3225	19.98
157.3	.2455	10.92	.3768	16.77	.5655	25.17
187.3	.2955	11.04	.4492	16.79	.6155	23.00
205.2	.2905	9.91	.4999	17.05	.7605	25.94
954.0	1.7770	13.04	2.3395	17.17	2.5970	19.06
130.2	.1640	8.82	.3203	17.22	.5140	27.63
110.1	.1525	9.70	.2725	17.33	.4025	25.59
141.1	.2385	11.83	.3516	17.44	.4985	24.73
141.5	.1678	8.30	.3534	17.48	.5478	27.10
140.7	.2170	10.80	.3539	17.61	.5470	27.21
109.3	.1840	11.78	.2753	17.63	.3940	25.23
161.1	.1915	8.32	.4071	17.69	.6515	28.31
107.7	.1340	8.71	.2753	17.89	.4040	26.26
128.9	.1940	10.54	.3309	17.97	.4940	26.83
119.9	.1755	10.25	.3080	17.98	.5055	29.51
122.1	.2040	11.70	.3146	18.04	.4040	23.16
132.9	.2210	11.64	.3448	18.16	.4310	22.70
250.1	.2560	7.17	.6491	18.17	1.1060	30.96
126.9	.1640	9.05	.3328	18.36	.5640	31.11
128.6	.2355	12.82	.3374	18.36	.4855	26.43
139.5	.1863	9.35	.3681	18.47	.6363	31.93
174.5	.2615	10.49	.4615	18.51	.7115	28.54
192.9	.3460	12.56	.5116	18.57	.6960	25.26
138.7	.2863	14.45	.3713	18.74	.4963	25.05

**FRAGMENT WEIGHT-PRESENTED AREA DATA
FOR TEST NO. QD-155-02**

Polar Zones 0°-180°

No. of Frags Selected for Measurements = 236

Frag Wt (Grains)	Minimum Area	Presented Area (in. ²)		Average Area	Gamma (in. ² /lb)	Maximum Area	Gamma (in. ² /lb)
		Gamma (in. ² /lb)					
206.7	.2560	8.67	.5554	18.81	.7760	26.28	
218.4	.3475	11.14	.5956	19.09	.7875	25.24	
218.7	.4130	13.22	.5974	19.12	.9430	30.18	
108.8	.2310	14.86	.2979	19.16	.4010	25.80	
109.4	.1255	8.03	.3011	19.27	.4055	25.95	
206.1	.2805	9.53	.5717	19.42	.9805	33.30	
123.6	.1755	9.94	.3430	19.43	.4955	28.06	
131.5	.1885	10.03	.3666	19.52	.5985	31.86	
158.1	.2630	11.64	.4417	19.56	.6630	29.35	
154.8	.3070	13.88	.4332	19.59	.5670	25.64	
128.7	.2355	12.81	.3630	19.74	.5055	27.49	
104.8	.1540	10.29	.2965	19.80	.4440	29.66	
119.6	.1940	11.35	.3428	20.06	.4840	28.33	
166.3	.2590	10.90	.4809	20.24	.8090	34.05	
118.9	.1985	11.69	.3441	20.26	.5585	32.88	
101.3	.1940	13.41	.2959	20.45	.4340	29.99	
132.3	.2455	12.99	.3899	20.63	.5955	31.51	
122.7	.2855	16.29	.3705	21.14	.4855	27.70	
100.8	.1755	12.19	.3049	21.17	.4955	34.41	
109.9	.2810	17.90	.3391	21.60	.4110	26.18	
101.9	.1740	11.95	.3253	22.34	.4740	32.56	
118.4	.1530	9.05	.3824	22.61	.5730	33.88	
106.2	.2640	17.40	.3434	22.63	.4440	29.27	
140.5	.2560	12.75	.4785	23.84	.7560	37.67	
103.5	.4205	28.44	.6924	46.83	1.0805	73.08	
211.3	.7640	25.31	1.4815	49.08	2.5840	85.60	
148.0	.5765	27.27	1.0584	50.06	1.8065	85.44	
102.4	.3790	25.91	.7784	53.21	1.3490	92.22	

FRAGMENT HAZARD INVESTIGATION

Test Number: QD-155-03

Items Tested: M107 155mm Projectile containing 15 lb of TNT explosive and equipped with a modified M564 Nose Fuze assembled with a Hercules Special Blasting Cap.

Number of Firings and Dates: 1 - 10 September 1975
1 - 12 September 1975
1 - 13 September 1975

Number of Items per Firing: 2

Location of Test: NSWC/DL - Experimental Explosive Area

Arena Configuration: Polar Arena

Fragment Recovery - 0°-180° polar by 18° Azimuthal

Fragment Velocities - 0°-180° polar by 27° Azimuthal

Cluster Configuration: Two projectiles stacked horizontally with the projectile center-lines parallel and seven inches apart.

Meteorology:

10 September 1975	Barometric Pressure - 32.08 in. Hg.
	Temperature - 72°F
12 September 1975	Barometric Pressure - 29.99 in. Hg.
	Temperature - 75°F
13 September 1975	Barometric Pressure - 30.12 in. Hg.
	Temperature - 80°F

Instrumentation: Fragment Velocity - Five high speed motion picture cameras; black and white film.

Post Test Comments: Largest concentration of fragments appear to be in polar zones 65°-105°.

The number and size of fragment penetration has increased, as compared to the second test (QD-155-02).

**FRAGMENT VELOCITIES AVERAGED
FOR THE THREE FIRINGS OF
TEST NO. QD-155-03**

Polar Zone (deg)	Avg Frag Velocity* (ft/s)
0- 5	1460.61
5- 10	1592.12
10- 15	1273.03
15- 20	1269.97
20- 25	**
25- 30	1196.17
30- 35	**
35- 40	**
40- 45	2831.74
45- 50	3676.67
50- 55	3143.72
55- 60	2763.61
60- 65	2815.89
65- 70	3206.75
70- 75	3165.91
75- 80	2547.04
80- 85	3831.92
85- 90	3984.76
90- 95	3954.46
95-100	4167.52
100-105	3894.43
105-110	2984.75
110-115	**
115-120	1200.24
120-125	1379.38
125-130	1207.29
130-135	1103.70
135-140	**
140-145	1044.42
145-150	1222.49
150-155	1089.37
155-160	**
160-165	1222.49
165-170	**
170-175	1842.67
175-180	1730.66

*Velocities recorded at 25.0 ft stand-off
**Instrumentation failure

**FRAGMENT WEIGHT AND NUMBER TOTAL COMBINED FOR
POLAR ZONES 0°-180° OF TEST NO. QD-155-03
(THREE FIRINGS)**

<u>Weight Group (Grains)</u>	<u>No. of Frag</u>	<u>Total Weight</u>
.1- 100.0	844.0	19622.7
100.0- 300.0	214.0	37171.3
300.0- 500.0	66.0	25665.6
500.0- 600.0	19.0	10484.0
600.0- 700.0	16.0	10101.2
700.0- 800.0	20.0	14920.4
800.0- 900.0	16.0	13506.9
900.0-1000.0	6.0	5646.9
1000.0-1200.0	12.0	12815.2
1200.0-1400.0	20.0	26145.8
1400.0-1700.0	17.0	26539.6
1700.0-2000.0	8.0	14905.3
2000.0-2500.0	9.0	20093.0
2500.0-3000.0	4.0	11046.3
3000.0 +	18.0	114655.9

FRAGMENT WEIGHT-PRESENTED AREA DATA FOR TEST NO. QD-155-03

Polar Zones 0°-180°

No. of Frags Selected for Measurements = 236

Frag Wt (Grains)	Presented Area (in. ²)		Average Area	Gamma (in. ² /lb)	Maximum Area	Gamma (in. ² /lb)
	Minimum Area	Gamma (in. ² /lb)				
23410.4	4.0000	1.20	10.8250	3.24	19.8000	5.92
10086.6	4.3000	2.98	5.6875	3.95	8.7000	6.04
14811.3	6.2000	2.93	9.4000	4.44	12.9000	6.10
4454.6	2.6000	4.09	3.0813	4.84	3.8000	5.97
6817.0	2.6030	2.67	4.7461	4.87	7.8430	8.05
3741.8	1.8930	3.54	2.7386	5.12	3.6930	6.91
2956.4	1.4893	3.53	2.2924	5.43	3.0893	7.31
3072.1	1.6000	3.65	2.3969	5.46	3.0000	6.84
3149.3	1.4450	3.21	2.5944	5.77	4.2650	9.48
2299.1	1.4055	4.28	1.9368	5.90	2.4755	7.54
2027.5	1.2750	4.40	1.7125	5.91	2.1550	7.44
2260.5	1.4765	4.57	1.9103	5.92	2.3365	7.24
3493.4	1.7520	3.51	2.9789	5.97	4.3320	8.68
3119.9	2.0000	4.49	2.7375	6.14	3.8000	8.53
2630.8	1.6885	4.49	2.3191	6.17	3.1285	8.32
3183.2	1.4100	3.10	2.8331	6.23	4.0400	8.88
7914.0	3.0000	2.65	7.0875	6.27	12.8000	11.32
7218.2	4.1000	3.98	6.4813	6.29	11.8000	11.44
2248.2	1.3878	4.32	2.0353	6.34	2.6378	8.21
1768.3	1.1735	4.65	1.6035	6.35	2.1035	8.33
2009.0	1.0770	3.75	1.8283	6.37	2.7370	9.54
4164.6	1.9205	3.23	3.8536	6.48	6.6205	11.13
3214.1	1.6125	3.51	2.9956	6.52	4.6325	10.09
2405.5	1.4225	4.14	2.2506	6.55	3.2125	9.35
1227.3	.8690	4.96	1.1853	6.76	1.5590	8.89
1417.4	.9435	4.66	1.3698	6.76	1.8435	9.10
4494.8	2.4270	3.78	4.3939	6.84	7.4370	11.58
1658.7	1.3835	5.84	1.6579	7.00	2.0035	8.46
1698.8	1.2173	5.02	1.7023	7.01	2.2773	9.38
2317.6	1.4960	4.52	2.3310	7.04	3.5460	10.71
1201.5	.9105	5.30	1.2143	7.07	1.5105	8.80
4922.2	3.7000	5.26	4.9812	7.08	6.2000	8.82
11244.6	.9720	5.47	1.2739	7.16	1.6720	9.40
1585.6	1.1210	4.95	1.6298	7.19	2.3410	10.33
2856.1	1.7290	4.24	2.9609	7.26	4.5690	11.20
3388.4	1.8500	3.82	3.5250	7.28	6.0000	12.40
1768.3	1.1295	4.47	1.8576	7.35	2.3195	9.18
939.9	.7838	5.84	.9981	7.43	1.2638	9.41
1910.2	1.2000	4.40	2.0519	7.52	3.3300	12.20
1938.0	.9175	3.31	2.1044	7.60	3.6275	13.10
901.0	.7523	5.84	.9785	7.60	1.1423	8.87
1891.7	1.1610	4.30	2.0566	7.61	3.0510	11.29
1354.1	1.1050	5.71	1.4781	7.64	1.9650	10.16
1449.2	.8170	3.95	1.5826	7.64	2.5070	12.11
1384.8	1.2205	6.17	1.5143	7.65	1.8505	9.35
1891.7	1.2430	4.60	2.0799	7.70	3.3730	12.48
1009.0	.7720	5.36	1.1095	7.70	1.4820	10.28
1802.2	1.1115	4.32	1.9828	7.70	3.0515	11.85
1934.9	1.2115	4.38	2.1315	7.71	3.4115	12.34
1120.3	.8435	5.27	1.2398	7.75	1.7935	11.21
1447.9	1.2310	5.95	1.6029	7.75	2.0510	9.92
1250.6	.9205	5.15	1.3874	7.77	1.8805	10.53
1140.5	.7930	4.87	1.2768	7.84	1.9330	11.86

**FRAGMENT WEIGHT-PRESENTED AREA DATA
FOR TEST NO. QD-155-03**

Polar Zones 0°-180°

No. of Frags Selected for Measurements = 236

Frag Wt (Grains)	Presented Area (in. ²)		Average Area	Gamma (in. ² /lb)	Maximum Area	Gamma (in. ² /lb)
	Minimum Area	Gamma (in. ² /lb)				
1081.0	.9960	6.45	1.2204	7.90	1.4860	9.62
1664.9	.9555	4.02	1.8805	7.91	3.2555	13.69
1386.5	1.0565	5.33	1.5703	7.93	2.0565	10.38
1345.7	1.0065	5.24	1.5265	7.94	2.3165	12.05
2189.5	1.3005	4.16	2.4880	7.95	4.2305	13.53
998.1	.7305	5.12	1.1343	7.95	1.6905	11.86
2603.0	1.3510	3.63	2.9991	8.07	4.5010	12.10
1040.9	.9698	6.52	1.2029	8.09	1.4698	9.88
1657.2	.9155	3.87	1.9161	8.09	2.9755	12.57
700.9	.5040	5.03	.8140	8.13	1.0340	10.33
1082.5	.7958	5.15	1.2633	8.17	1.9258	12.45
1396.1	.7500	3.76	1.6625	8.34	2.7000	13.54
709.6	.5468	5.39	.8505	8.39	1.2968	12.79
1360.8	1.0065	5.18	1.6315	8.39	2.4565	12.64
1058.2	.8480	5.61	1.2736	8.43	2.0480	13.55
1470.2	1.1925	5.68	1.7719	8.44	2.4725	11.77
1638.7	1.1470	4.90	1.9808	8.46	3.0070	12.84
869.1	.6190	4.99	1.0509	8.46	1.5990	12.88
767.6	.6530	5.95	.9292	8.47	1.1430	10.42
768.5	.6145	5.60	.9314	8.48	1.2545	11.43
1346.7	.9410	4.89	1.6398	8.52	2.6810	13.94
2336.1	1.4265	4.27	2.8665	8.59	4.2965	12.87
931.5	.7065	5.31	1.1559	8.69	1.6465	12.37
1201.8	.6395	3.72	1.4958	8.71	2.3795	13.86
741.8	.6500	6.13	.9269	8.75	1.1700	11.04
564.9	.4430	5.49	.7061	8.75	1.0830	13.54
1574.3	1.0985	4.88	1.9685	8.75	3.2885	14.62
810.7	.6575	5.68	1.0150	8.76	1.4575	12.58
1218.6	.8840	5.08	1.5328	8.80	2.2940	13.18
742.7	.6475	6.10	.9531	8.98	1.4175	13.36
632.7	.4528	5.01	.8140	9.01	1.3528	14.97
1063.5	.6880	4.53	1.3718	9.03	2.3780	15.65
1352.1	1.0310	5.34	1.7441	9.03	2.5310	13.10
1688.0	1.2545	5.20	2.1883	9.05	2.7445	11.38
706.2	.5690	5.64	.9177	9.10	1.3790	13.67
625.5	.5260	5.89	.8147	9.12	1.1360	12.71
1373.3	1.0155	5.18	1.7930	9.14	2.6355	13.43
536.8	.3900	5.09	.7025	9.16	1.0400	13.56
501.0	.5178	7.23	.6590	9.21	.8378	11.71
1627.9	1.0230	4.40	2.1443	9.22	3.5130	15.11
813.4	.6105	5.25	1.0780	9.28	1.4605	12.57
820.5	.7635	6.51	1.0885	9.29	1.4535	12.40
770.2	.5920	5.38	1.0245	9.31	1.4920	13.56
819.2	.6628	5.66	1.0915	9.33	1.6028	13.70
973.8	.7365	5.29	1.3259	9.53	1.9965	14.35
732.5	.7175	6.86	1.0038	9.59	1.2675	12.11
825.6	.6880	5.83	1.1361	9.63	1.6280	13.80
665.3	.4675	4.92	.9162	9.64	1.4375	15.12
564.2	.4015	4.98	.7771	9.64	1.0515	13.05
615.7	.4560	5.18	.8554	9.72	1.1560	13.14
647.8	.4920	5.32	.9014	9.74	1.4820	16.01

**FRAGMENT WEIGHT-PRESENTED AREA DATA
FOR TEST NO. QD-155-03**

Polar Zones 0°-180°

No. of Frags Selected for Measurements = 236

Frag Wt (Grains)	Presented Area (in. ²)		Average Area	Gamma (in. ² /lb)	Maximum Area	Gamma (in. ² /lb)
	Minimum Area	Gamma (in. ² /lb)				
1486.1	1.1490	5.41	2.0784	9.79	3.1490	14.83
561.8	.4760	5.93	.7879	9.82	1.1760	14.65
902.6	.6925	5.37	1.2688	9.84	1.9525	15.14
1214.5	.8040	4.63	1.7190	9.91	3.0040	17.31
591.5	.5253	6.22	.8409	9.95	1.3153	15.57
525.1	.4500	6.00	.7475	9.96	1.0200	13.60
1448.0	.8135	3.93	2.0873	10.09	3.6935	17.86
525.2	.4930	6.57	.7580	10.10	1.1130	14.83
731.3	.6390	6.12	1.0603	10.15	1.6990	16.26
619.1	.6405	7.24	.8980	10.15	1.2005	13.57
842.2	.6625	5.51	1.2256	10.19	1.7425	14.48
893.3	.7110	5.57	1.3029	10.21	1.9910	15.60
517.7	.4345	5.88	.7570	10.24	1.1145	15.07
825.5	.6165	5.23	1.2146	10.30	1.8565	15.74
707.9	.5020	4.96	1.0464	10.35	1.6220	16.04
839.9	.7310	6.09	1.2441	10.37	1.9710	16.43
756.4	.6520	6.03	1.1264	10.42	1.5920	14.73
1277.3	.8375	4.59	1.9031	10.43	3.0075	16.48
794.7	.7405	6.52	1.1880	10.46	1.8105	15.95
657.3	.5790	6.17	.9871	10.51	1.4390	15.32
829.7	.6895	5.82	1.2501	10.55	2.0895	17.63
1375.4	1.0175	5.18	2.0956	10.67	2.8975	14.75
737.9	.6150	5.83	1.1275	10.70	1.8450	17.50
243.6	.2055	5.91	.3724	10.70	.6355	18.26
879.3	.7725	6.15	1.3450	10.71	2.1725	17.30
1600.1	1.1715	5.12	2.4546	10.74	4.0515	17.72
512.6	.4730	6.46	.7905	10.79	1.1830	16.15
482.3	.3830	5.56	.7442	10.80	1.1830	17.17
642.2	.4620	5.04	.9970	10.87	1.4620	15.94
454.2	.4090	6.30	.7077	10.91	1.0090	15.55
890.5	.7155	5.62	1.3918	10.94	2.2655	17.81
660.7	.4390	4.65	1.0421	11.04	1.6590	17.58
781.2	.6325	5.67	1.2331	11.05	1.8225	16.33
591.4	.4465	5.28	.9340	11.06	1.4265	16.88
495.9	.4160	5.87	.7835	11.06	1.1660	16.46
473.2	.4460	6.60	.7485	11.07	1.1360	16.80
869.8	.8520	6.86	1.3833	11.13	1.9420	15.63
621.5	.6435	7.25	.9910	11.16	1.2635	14.23
612.7	.4505	5.15	.9792	11.19	1.4505	16.57
603.4	.5265	6.11	.9727	11.28	1.5765	18.29
585.3	.5505	6.58	.9467	11.32	1.4605	17.47
1079.8	1.0820	7.01	1.7526	11.36	2.7220	17.65
447.9	.4390	6.86	.7277	11.37	1.0590	16.55
590.8	.5705	6.76	.9611	11.39	1.3305	15.76
1426.6	1.3480	6.61	2.3211	11.39	3.3580	16.48
607.1	.5250	6.05	1.0025	11.56	1.5650	18.04
633.4	.5720	6.32	1.0483	11.58	1.4220	15.72
627.0	.6375	7.12	1.0381	11.59	1.6675	18.62
538.8	.4905	6.37	.8930	11.60	1.4605	18.97
546.4	.4750	6.09	.9106	11.67	1.3750	17.62
487.9	.4775	6.85	.8144	11.68	1.2975	18.62

**FRAGMENT WEIGHT-PRESENTED AREA DATA
FOR TEST NO. QD-155-03**

Polar Zones 0°-180°

No. of Frags Selected for Measurements = 236

Frag Wt (Grains)	Presented Area (in. ²)		Average Area	Gamma (in. ² /lb)	Maximum Area	Gamma (in. ² /lb)
	Minimum Area	Gamma (in. ² /lb)				
293.3	.2685	6.41	.4916	11.73	.7185	17.15
1309.9	1.0320	5.51	2.2008	11.76	3.5320	18.87
598.6	.4965	5.81	1.0103	11.81	1.5465	18.08
629.8	.4780	4.76	1.0636	11.82	1.7480	19.43
1086.4	1.1460	7.38	1.8523	11.93	2.6460	17.05
754.3	.5573	5.17	1.2673	11.95	1.8773	17.42
554.7	.5110	6.45	.9529	12.02	1.5110	19.07
404.5	.3800	6.58	.6994	12.10	1.0600	18.34
456.5	.4755	7.33	.7900	12.12	1.2875	19.76
707.8	.4685	4.63	1.2285	12.15	2.0385	20.16
514.7	.4990	6.79	.9040	12.29	1.3790	18.75
454.9	.5045	7.76	.8014	12.33	1.1845	18.23
1324.2	.8190	4.33	2.4109	12.74	7.3690	38.95
259.3	.3355	9.06	.4730	12.77	.6655	17.97
475.3	.4490	6.61	.8671	12.77	1.2190	17.95
316.5	.3115	6.89	.5821	12.87	.8515	18.83
797.4	.5915	5.19	1.4721	12.92	2.5415	22.31
570.0	.5635	6.92	1.0529	12.93	1.7535	21.53
510.2	.4950	6.79	.9462	12.98	1.5850	21.75
218.8	.2140	6.85	.4065	13.01	.5340	17.08
795.9	.8310	7.31	1.4854	13.06	2.1110	18.57
278.0	.2770	6.97	.5207	13.11	.7170	18.05
459.8	.3890	5.92	.8634	13.14	1.3590	20.69
819.5	.7415	6.33	1.5528	13.26	2.4315	20.77
238.6	.2870	8.42	.4551	13.35	.6370	18.69
118.2	.1295	7.67	.2295	13.59	.3295	19.51
233.7	.2640	7.91	.4540	13.60	.6940	20.79
148.7	.1295	6.10	.2901	13.66	.4095	19.28
192.4	.2340	8.51	.3784	13.77	.5440	19.79
229.0	.2570	7.86	.4514	13.80	.6670	20.39
284.4	.3370	8.29	.5676	13.97	.8670	21.34
304.1	.3300	7.60	.6131	14.11	.8400	19.34
330.9	.3575	7.56	.5676	14.12	.9975	21.10
361.3	.3975	7.70	.7381	14.30	1.1075	21.46
105.6	.0795	5.27	.2176	14.43	.3395	22.50
183.2	.2195	8.39	.3814	14.57	.4995	19.09
1031.8	1.5805	10.72	2.1511	14.59	2.6205	17.78
304.1	.4030	8.29	.6361	14.64	.8930	20.56
196.2	.2170	7.74	.4214	15.03	.6070	21.66
275.3	.2885	7.34	.5966	15.17	.8985	22.85
243.0	.3485	10.04	.5291	15.24	.7385	21.27
184.9	.2525	9.56	.4056	15.36	.5325	20.16
316.9	.4251	9.31	.7002	15.47	.9415	20.80
176.4	.2100	8.33	.3906	15.50	.5700	22.62
213.4	.2770	9.09	.4739	15.54	.7370	24.18
188.9	.3118	11.55	.4230	15.67	.5618	20.82
1021.3	1.8450	12.65	2.3038	15.79	2.6150	17.92
858.7	1.8150	14.80	1.9644	16.01	2.1550	17.57
169.5	.1985	8.20	.3885	16.04	.5985	24.72
430.7	.4905	7.97	.9899	16.09	1.4905	24.22
173.0	.2585	10.46	.4079	16.50	.6485	26.24

**FRAGMENT WEIGHT-PRESENTED AREA DATA
FOR TEST NO. QD-155-03**

Polar Zones 0°-180°

No. of Frags Selected for Measurements = 236

Frag Wt (Grains)	Minimum Area	Presented Area (in. ²)		Average Area	Gamma (in. ² /lb)	Maximum Area	Gamma (in. ² /lb)
		Gamma (in. ² /lb)	Gamma (in. ² /lb)				
146.5	.2495	11.92	.3470	16.58	.4195	20.04	
111.8	.1325	8.30	.2688	16.83	.3925	24.58	
110.7	.1773	11.21	.2673	16.90	.3473	21.96	
147.1	.2255	10.73	.3555	16.92	.5155	24.53	
152.0	.2740	12.62	.3715	17.11	.5240	24.13	
171.1	.2470	10.11	.4201	17.19	.6970	28.52	
474.4	.6340	9.35	1.1671	17.22	1.824	26.91	
176.9	.3355	13.28	.4567	18.07	.535	21.19	
207.6	.2700	9.10	.5387	18.17	.7100	23.94	
164.0	.2685	11.46	.4497	19.20	.6685	28.53	
108.9	.2265	14.56	.3040	19.54	.4065	26.13	
117.5	.1355	8.07	.3286	19.58	.5355	31.90	
169.1	.2870	11.88	.4732	19.59	.7070	29.27	
123.3	.2410	13.68	.3573	20.28	.4510	25.60	
103.9	.1070	7.21	.3120	21.02	.5770	38.87	
402.3	.9430	16.41	1.2174	21.18	1.3530	23.54	
100.8	.2010	13.96	.3054	21.21	.5110	35.49	
129.5	.2840	15.35	.4127	22.31	.5240	33.73	
173.7	.1975	7.96	.5612	22.62	.8275	33.35	
113.7	.2455	15.11	.3680	22.66	.5055	31.12	
375.9	1.0060	18.73	1.2310	22.92	1.3760	25.62	
102.3	.1940	13.27	.3409	23.32	.5340	36.54	
156.8	.2885	12.88	.5479	24.46	.8585	38.33	
100.8	.3118	21.65	.3843	26.68	.4718	32.76	
368.0	1.2105	23.03	1.5911	30.27	1.9705	37.48	
100.4	.2670	18.62	.5076	35.39	.7870	54.87	
715.6	1.7000	16.63	4.0188	39.31	6.2000	60.65	
151.3	.5535	25.61	1.1010	50.94	1.8535	85.75	

FRAGMENT HAZARD INVESTIGATION

Test Number: QD-155-04

Item Tested: M107 155mm Projectile containing 15 lb of TNT explosive and equipped with a modified M564 Nose Fuze assembled with a Hercules Special Blasting Cap.

Number of Firings and Dates: 1 - 23 October 1975
1 - 28 October 1975
1 - 29 October 1975

Number of Items per Firing: 4

Location of Test: NSWC/DL -- Experimental Explosive Area

Arena Configuration: Polar Arena

Fragment Recovery -- 0°-180° polar by 15° Azimuthal

Fragment Velocities -- 0°-180° polar by 27° Azimuthal

Cluster Configuration: Four projectiles in a horizontal position; two projectiles stacked on top of the other two projectiles, with their centerlines seven inches apart forming a cube.

Meteorology:

23 October 1975	Barometric Pressure	-- 30.12 in. Hg.
	Temperature	-- 75°F
28 October 1975	Barometric Pressure	-- 30.20 in. Hg.
	Temperature	-- 70°F
29 October 1975	Barometric Pressure	-- 30.10 in. Hg.
	Temperature	-- 72°F

Instrumentation: Fragment Velocity -- Five high speed motion picture cameras; black and white film.

Post Test Comments: Largest concentration of fragments appear to be in the polar zone 60°-110°. Celotex bundles in the 80°-95° polar zones were blown out of the circumference of the area. Two fragment holes two inches in length and ten inches in length and approximately four inches wide were found in the witness panels. One fragment approximately twelve inches long and approximately three inches wide was found just outside the arena circumference.

**FRAGMENT VELOCITIES AVERAGED
FOR THE THREE FIRINGS OF
TEST NO. QD-155-04**

Polar Zone (deg)	Avg Frag Velocity* (ft/s)
0- 5	2717.03
5- 10	2920.63
10- 15	4477.24
15- 20	3099.85
20- 25	5150.75
25- 30	3848.05
30- 35	2608.05
35- 40	4587.05
40- 45	6407.97
45- 50	6493.31
50- 55	6929.46
55- 60	7032.55
60- 65	6357.65
65- 70	5190.42
70- 75	6131.62
75- 80	5885.30
80- 85	5907.14
85- 90	5821.82
90- 95	5814.21
95-100	6158.24
100-105	5578.99
105-110	5337.17
110-115	3990.60
115-120	3916.44
120-125	3369.39
125-130	1862.67
130-135	2016.13
135-140	2090.30
140-145	1916.01
145-150	**
150-155	**
155-160	2934.53
160-165	2740.99
165-170	4535.89
170-175	5190.35
175-180	3820.31

*Velocities recorded at 25.0 ft stand-off
**Instrumentation failure

**FRAGMENT WEIGHT AND NUMBER TOTALS COMBINED FOR
POLAR ZONES 0°-180° OF TEST NO. QD-155-04
(THREE FIRINGS)**

<u>Weight Group (Grains)</u>	<u>No. of Frgs</u>	<u>Total Weight</u>
.1- 100.0	1331.0	29333.5
100.0- 300.0	278.0	48822.6
300.0- 500.0	92.0	35642.9
500.0- 600.0	25.0	13542.4
600.0- 700.0	33.0	21385.0
700.0- 800.0	21.0	15686.6
800.0- 900.0	14.0	11624.6
900.0-1000.0	13.0	12353.4
1000.0-1200.0	14.0	15252.5
1200.0-1400.0	17.0	21822.8
1400.0-1700.0	17.0	26108.0
1700.0-2000.0	11.0	20397.0
2000.0-2500.0	8.0	18826.0
2500.0-3000.0	9.0	25458.0
3000.0 +	23.0	129940.7

**FRAGMENT WEIGHT-PRESENTED AREA DATA
FOR TEST NO. QD-155-04**

Polar Zones 0°-180°

No. of Frags Selected for Measurements = 236

Frag Wt (Grains)	Minimum Area	Presented Area (in. ²)		Average Area	Gamma (in. ² /lb)	Maximum Area	Gamma (in. ² /lb)
		Gamma (in. ² /lb)					
16287.9	3.7000	1.59	8.7375	3.76	12.0000	5.16	
10399.8	3.4000	2.29	5.6750	3.82	7.4000	4.98	
4916.0	1.2000	1.71	2.7875	3.97	4.4000	6.27	
6755.3	2.8500	2.95	4.0844	4.23	5.8000	6.01	
8265.9	2.7000	2.29	5.1250	4.34	7.3000	6.18	
5482.3	2.1000	2.68	3.5875	4.58	5.3000	6.77	
3964.0	1.8970	3.35	2.6626	4.70	3.3870	5.98	
4153.8	2.1940	3.70	2.7978	4.71	3.6940	6.23	
4777.1	1.9645	2.88	3.2233	4.72	4.4645	6.54	
8225.7	3.0000	2.55	5.6188	4.78	7.6000	6.47	
4811.1	2.7500	4.00	3.3781	4.92	4.0500	5.89	
4820.3	2.2000	3.19	3.5156	5.11	4.9000	7.12	
2854.6	1.3270	3.25	2.1120	5.18	3.1170	7.64	
3198.6	1.5000	3.28	2.3813	5.21	3.5000	7.66	
3351.4	1.7300	3.61	2.5081	5.24	3.2800	6.85	
5473.0	2.2000	2.81	4.1375	5.29	6.8000	8.70	
2816.0	1.5925	3.96	2.1556	5.36	2.7825	6.92	
2831.4	1.2978	3.21	2.1696	5.36	2.8678	7.09	
2860.7	1.5570	3.81	2.2195	5.43	2.8570	6.99	
3248.0	1.7948	3.87	2.5316	5.46	3.2648	7.04	
3084.5	2.0000	4.54	2.4156	5.48	2.8500	6.47	
2670.9	1.4570	3.82	2.0916	5.48	2.8670	7.51	
3610.6	1.9000	3.68	2.8313	5.49	3.9000	7.56	
3127.7	1.7675	3.96	2.5044	5.60	3.4575	7.74	
2718.8	1.4870	3.83	2.1970	5.66	3.4370	8.85	
2359.2	1.3348	3.96	1.9279	5.72	2.5948	7.70	
1692.7	1.0550	4.36	1.3869	5.74	1.6750	6.93	
2493.5	1.4895	4.18	2.0451	5.74	2.5695	7.21	
3686.2	1.4125	2.68	3.0525	5.80	4.7825	9.08	
5738.4	1.6000	1.95	4.8375	5.90	7.5000	9.15	
2353.1	1.1795	3.51	1.9920	5.93	2.8395	8.45	
1660.3	1.2990	5.48	1.4103	5.95	1.7190	7.25	
3940.8	1.7805	3.16	3.3949	6.03	4.9005	8.70	
2283.6	1.3980	4.29	1.9930	6.11	2.6380	8.09	
2376.2	1.4375	4.23	2.1406	6.31	3.0975	9.12	
1016.8	.4905	3.38	.9180	6.32	1.4205	9.78	
1788.3	1.1250	4.40	1.6244	6.36	2.1150	8.28	
8622.3	1.3000	1.06	7.8625	6.38	14.4000	11.69	
2333.0	1.3370	4.01	2.1351	6.41	2.9170	8.75	
1947.3	1.1835	4.25	1.7873	6.42	2.2935	8.24	
2419.4	1.9000	5.50	2.2469	6.50	2.5500	7.38	
2786.7	.9885	2.48	2.6854	6.75	4.6685	11.73	
1928.8	1.6035	5.82	1.8623	6.76	2.1735	7.89	
1851.6	.8825	3.34	1.7950	6.79	2.6625	10.07	
803.1	.5400	4.71	.7802	6.80	1.0500	9.15	
1737.4	.8570	3.45	1.7026	6.86	2.7670	11.15	
1426.5	.9105	4.47	1.3980	6.86	1.8205	8.93	
1588.1	1.2290	5.42	1.5571	6.86	1.8390	8.11	
2950.3	1.3650	3.20	2.9475	6.90	4.7050	11.01	
1493.3	.9935	4.66	1.4741	6.91	1.8035	8.45	
999.0	.6523	4.57	.9866	6.91	1.2223	8.56	

**FRAGMENT WEIGHT-PRESENTED AREA DATA
FOR TEST NO. QD-155-04**

Polar Zones 0°-180°

No. of Frags Selected for Measurements = 236

Frag Wt (Grains)	Presented Area (in. ²)		Average Area	Gamma (in. ² /lb)	Maximum Area	Gamma (in. ² /lb)
	Minimum Area	Gamma (in. ² /lb)				
1359.6	.9405	4.84	1.3436	6.92	2.0605	10.61
1559.6	.9680	4.34	1.5593	7.00	2.0680	9.28
1277.2	1.0990	6.02	1.2796	7.01	1.5390	8.43
1027.2	.5213	3.55	1.0294	7.01	1.5913	10.84
1962.7	1.1140	3.97	1.9778	7.05	2.8540	10.18
2928.6	1.3155	3.14	3.0436	7.27	4.9355	11.80
2208.0	1.5000	4.76	2.3013	7.30	3.2300	10.24
1051.8	.8445	5.62	1.1295	7.52	1.3945	9.28
1356.3	.8065	4.16	1.4646	7.56	2.2565	11.65
720.8	.5185	5.04	.7791	7.57	.9085	8.82
1968.9	1.1120	3.95	2.1389	7.60	3.4820	12.38
1392.0	1.0165	5.11	1.5165	7.63	2.2365	11.25
806.3	.6330	5.50	.8830	7.67	1.2430	10.79
988.9	.9830	6.32	1.0874	7.70	1.3030	9.22
1867.0	1.2430	4.66	2.0574	7.71	2.7730	10.40
1135.6	.7850	4.84	1.2681	7.82	1.9650	12.11
1153.4	.7535	4.57	1.3048	7.92	2.0135	12.22
1427.8	.9995	4.90	1.6176	7.93	2.1795	10.69
1279.1	.8780	4.80	1.4599	7.99	2.2080	12.08
1545.1	.8770	3.97	1.7645	7.99	2.8770	13.03
1438.3	.8310	4.04	1.6466	8.01	2.8210	13.73
943.7	.4450	3.30	1.0819	8.02	1.3850	10.27
758.7	.5830	5.38	.8742	8.07	1.1730	10.82
905.4	.7005	5.42	1.0493	8.11	1.3105	10.13
1621.7	1.1655	5.03	1.9093	8.24	2.7655	11.94
1739.0	1.0863	4.37	2.0488	8.25	2.9263	11.78
1274.3	1.0080	5.54	1.5205	8.35	2.0880	11.47
1688.0	1.1375	4.72	2.0206	8.38	3.1975	13.26
1202.9	.9010	5.24	1.4416	8.39	2.1810	12.69
700.9	.7143	7.13	.8424	8.41	1.0143	10.13
874.3	.7700	6.16	1.0544	8.44	1.3100	10.49
962.4	.7120	5.18	1.1620	8.45	1.7520	12.74
1210.5	.9165	5.30	1.4621	8.46	1.8865	10.91
830.2	.7730	6.52	1.0030	8.46	1.3430	11.32
1232.6	.7980	4.53	1.4936	8.48	2.4280	13.79
1154.1	.9635	5.24	1.4029	8.51	1.8435	11.18
1081.9	.7620	4.93	1.3239	8.57	2.0120	13.02
1160.5	.8150	4.92	1.4225	8.58	2.2250	13.42
596.9	.4675	5.48	.7331	8.60	1.1775	13.81
1310.9	.9140	4.88	1.6140	8.62	2.6940	14.39
665.1	.5175	5.45	.8200	8.63	1.2375	13.02
721.7	.5803	5.63	.8902	8.63	1.3103	12.71
1500.4	.7045	3.29	1.8695	8.72	2.6845	12.52
600.8	.5030	5.86	.7536	8.78	.9230	10.75
1481.8	.7965	3.93	1.7884	8.82	2.3465	11.58
914.6	.4905	3.75	1.1561	8.85	1.6305	12.48
1460.0	1.1120	5.33	1.8458	8.85	2.5220	12.09
619.7	.5645	6.38	.7839	8.85	1.1545	13.04
746.7	.0650	.61	.9525	8.93	1.6050	15.05
1234.2	1.0110	5.73	1.5804	8.96	2.5110	14.24
633.0	.6345	7.02	.8126	8.99	.9745	10.78

**FRAGMENT WEIGHT-PRESENTED AREA DATA
FOR TEST NO. QD-155-04**

Polar Zones 0°-180°

No. of Frags Selected for Measurements = 236

Frag Wt (Grains)	Presented Area (in. ²)		Average Area	Gamma (in. ² /lb)	Maximum Area	Gamma (in. ² /lb)
	Minimum Area	Gamma (in. ² /lb)				
1800.7	.8380	3.26	2.3143	9.00	3.6880	14.34
802.4	.6020	5.25	1.0333	9.01	1.8420	14.32
979.5	.9675	6.91	1.2669	9.05	1.6175	11.56
815.8	.5435	4.66	1.0604	9.10	1.5935	13.67
615.3	.5908	6.72	.8007	9.11	1.0708	12.18
769.3	.6890	6.27	1.0053	9.15	1.3590	12.37
516.5	.5825	7.89	.6750	9.15	.8025	10.88
690.4	.5915	6.00	.9077	9.20	1.1815	11.98
761.8	.6190	5.69	1.0021	9.21	1.5190	13.96
1226.0	.8370	4.78	1.6158	9.23	2.6670	15.23
1468.4	1.0260	4.89	1.9404	9.25	2.8760	13.71
576.0	.6263	7.61	.7612	9.25	.9663	11.74
942.1	.7598	5.65	1.2454	9.25	1.6998	12.63
561.7	.5015	6.25	.7434	9.26	1.0915	13.60
909.9	.5873	4.52	1.2060	9.28	1.9973	15.37
507.4	.4415	6.09	.6771	9.34	.9815	13.54
593.2	.4875	5.75	.7925	9.35	1.2175	14.37
907.1	.7365	5.68	1.2146	9.37	1.9765	15.25
1071.6	.6710	4.38	1.4373	9.39	2.1210	13.85
691.0	.5605	5.68	.9286	9.41	1.4105	14.29
761.3	.8525	7.84	1.0231	9.41	1.2825	11.79
684.4	.5545	5.67	.9207	9.42	1.4145	14.47
619.1	.4938	5.58	.8356	9.45	1.2738	14.40
665.4	.6293	6.62	.9011	9.48	1.3593	14.30
1464.5	.8975	4.29	1.9875	9.50	3.0675	14.66
1319.5	1.0125	5.37	1.7950	9.52	2.9425	15.61
505.2	.4530	6.28	.6924	9.59	1.0030	13.90
643.1	.4890	5.32	.8877	9.66	1.2990	14.14
597.5	.5390	6.31	.8265	9.68	1.1790	13.81
1054.5	.7040	4.67	1.4640	9.72	2.4540	16.29
1805.3	1.5710	6.09	2.5085	9.73	3.5910	13.92
952.9	.7303	5.36	1.3259	9.74	1.8403	13.52
770.8	.6150	5.59	1.0738	9.75	1.6050	14.58
721.3	.4945	4.80	1.0064	9.77	1.4345	13.92
529.0	.4768	6.31	.7386	9.77	1.1268	14.91
519.8	.3808	5.13	.7289	9.82	.9808	13.21
855.9	.8860	7.25	1.2016	9.83	1.6060	13.13
568.5	.4530	5.58	.7986	9.83	1.4330	17.64
639.9	.4830	5.28	.8999	9.84	1.3130	14.36
537.3	.4630	6.03	.7561	9.85	1.1730	15.28
632.0	.3545	3.93	.8964	9.93	1.3045	14.45
873.8	.5180	4.15	1.2411	9.94	1.9580	15.69
751.1	.5820	5.42	1.0670	9.94	1.7820	16.61
616.6	.4460	5.06	.8841	10.04	1.3860	15.73
596.0	.4402	5.17	.8576	10.07	1.0502	12.33
535.4	.4160	5.44	.7722	10.10	1.2060	15.77
1655.6	.9350	3.93	2.3925	10.12	4.2450	17.95
1232.2	.9340	5.31	1.7821	10.12	2.3640	13.43
507.2	.5800	8.00	.7356	10.15	.8900	12.28
769.8	.4690	4.26	1.1165	10.15	1.8890	17.18
537.5	.4253	5.54	.7809	10.17	1.2153	15.83

**FRAGMENT WEIGHT-PRESENTED AREA DATA
FOR TEST NO. QD-155-04**

Polar Zones 0°-180°

No. of Frags Selected for Measurements = 236

Frag Wt (Grains)	Minimum Area	Presented Area (in. ²) Gamma (in. ² /lb)	Average Area	Gamma (in. ² /lb)	Maximum Area	Gamma (in. ² /lb)
692.4	.6275	6.34	1.0138	10.25	1.5575	15.75
766.9	.6735	6.15	1.1273	10.29	1.5735	14.36
1119.8	.7830	4.89	1.6493	10.31	2.5630	16.02
595.5	.4960	5.83	.8779	10.32	1.3360	15.70
1025.9	.7170	4.89	1.5139	10.33	2.7270	18.61
806.8	.6650	5.77	1.1944	10.36	1.7050	14.79
751.1	.4620	4.31	1.1126	10.37	1.7420	16.23
501.7	.3645	5.09	.7445	10.39	1.1345	15.83
635.6	.3143	3.46	.9455	10.41	1.5043	16.57
1099.8	.8485	5.40	1.6379	10.42	2.7585	17.56
630.2	.4765	5.29	.9390	10.43	1.8165	20.18
610.7	.4220	4.84	.9151	10.49	1.5020	17.22
993.8	.9395	6.62	1.4958	10.54	2.2695	15.99
522.5	.5030	6.74	.7867	10.54	1.1430	15.31
626.8	.6175	6.90	.9506	10.62	1.3975	15.61
682.6	.4805	4.93	1.0411	10.68	1.4505	14.87
1099.6	.8530	5.43	1.6818	10.71	2.4730	15.74
1207.3	.8930	5.18	1.8555	10.76	3.0030	17.41
662.8	.5035	5.32	1.0210	10.78	1.8435	19.47
661.0	.5635	5.97	1.0254	10.86	1.6435	17.40
727.2	.7760	7.47	1.1348	10.92	1.5760	15.17
601.5	.5505	6.41	.9392	10.93	1.4705	17.11
632.7	.5520	6.11	.9945	11.00	1.5520	17.17
1358.7	1.0080	5.19	2.1480	11.07	3.6180	18.64
954.1	.5215	3.83	1.5109	11.08	2.4415	17.91
619.1	.3375	3.82	.9819	11.10	1.4375	16.25
688.2	.4390	4.47	1.0934	11.12	1.7490	17.79
861.9	.6310	5.12	1.3791	11.20	2.4610	19.99
726.4	.4858	4.68	1.1770	11.34	1.9058	18.36
660.4	.5003	5.30	1.0709	11.35	1.9403	20.57
687.0	.5520	5.62	1.1145	11.36	1.6020	16.32
1349.5	1.0205	5.29	2.1999	11.41	3.5505	18.42
574.9	.5360	6.53	.9416	11.47	1.3460	16.39
801.7	.8063	7.04	1.3263	11.58	1.9663	17.17
752.4	.4940	4.60	1.2709	11.82	2.1040	19.57
503.5	.4960	6.90	.8510	11.83	1.3660	18.99
642.1	.4703	5.13	1.1090	12.09	2.0303	22.13
729.6	.5010	4.81	1.2666	12.15	2.2010	21.12
664.6	.5688	5.99	1.1925	12.56	1.9988	21.05
872.7	.6670	5.35	1.5845	12.71	1.9870	15.94
680.7	.7235	7.44	1.2448	12.80	1.6535	17.00
530.7	.5820	7.68	.9764	12.88	1.3920	18.36
506.7	.4750	6.56	.9525	13.16	1.6050	22.17
680.2	.7650	7.87	1.3056	13.44	2.2550	23.21
503.1	.3280	4.56	.9724	13.53	1.6280	22.65
705.1	.4978	4.94	1.3803	13.70	2.3878	23.70
512.7	.5760	7.86	1.0110	13.80	1.3960	19.06
610.6	.4280	4.91	1.2293	14.09	1.8480	21.19
817.5	.8535	7.31	1.8404	15.76	2.7235	23.32
791.7	1.8095	16.00	2.2495	19.89	2.4395	21.57
802.2	1.8903	16.49	2.3184	20.23	2.5003	21.82
781.9	1.8303	16.39	2.2603	20.24	2.4403	21.85

FRAGMENT HAZARD INVESTIGATION

Test Number: QD-155-05

Item Tested: M107 155mm Projectile containing 15 lb of TNT explosive and equipped with a modified M564 Nose Fuze assembled with a Hercules Special Blasting Cap.

Number of Firings and Dates: 1 - 26 November 1975
1 - 2 December 1975
1 - 3 December 1975

Number of Items Per Firing: 4

Location of Test: NSWC/DL -- Experimental Explosive Area

Arena Configuration: Polar Arena

Fragment Recovery -- 0°-180° polar by 11° azimuthal

Fragment Velocities -- 0°-180° polar by 27° azimuthal

Cluster Configuration: Four projectiles in a horizontal row; positioned side by side with their axial centerlines seven inches apart.

Meteorology:

26 November 1975	Barometric Pressure	-- 30.22 in. Hg.
	Temperature	-- 55°F
2 December 1975	Barometric Pressure	-- 31.68 in. Hg.
	Temperature	-- 45°F
3 December 1975	Barometric Pressure	-- 29.95 in. Hg.
	Temperature	-- 47°F

Instrumentation: Fragment Velocity -- Five high speed motion picture cameras; black and white film.

Post Test Comments: Largest concentration of fragments appear to be in polar zones 85°-105°.

Fragment penetrations in the Celotex and witness panels compare to those in the single round detonation test QD-155-01. That is, no evidence of unusually large or excessive fragment penetrations in the witness panels.

**FRAGMENT VELOCITIES AVERAGED
FOR THE THREE FIRINGS OF
TEST NO. QD-155-05**

Polar Zone (deg)	Avg Frag Velocity* (ft/s)
0- 5	2413.68
5- 10	3079.17
10- 15	1880.38
15- 20	1380.12
20- 25	**
25- 30	1700.68
30- 35	1506.02
35- 40	**
40- 45	2403.34
45- 50	**
50- 55	1730.10
55- 60	2597.30
60- 65	2566.53
65- 70	2611.82
70- 75	3448.41
75- 80	3981.48
80- 85	4568.91
85- 90	4732.24
90- 95	4859.85
95-100	4699.26
100-105	4117.66
105-110	2016.26
110-115	2199.06
115-120	**
120-125	**
125-130	4032.26
130-135	**
135-140	**
140-145	**
145-150	**
150-155	**
155-160	**
160-165	**
165-170	1992.97
170-175	2752.76
175-180	2833.64

*Velocities recorded at 25.0 ft stand-off

**Instrumentation failure

**FRAGMENT WEIGHT AND NUMBER TOTALS COMBINED FOR
POLAR ZONES 0°-180° OF TEST NO. QD-155-05**

<u>Weight Group (Grains)</u>	<u>No. of Frag</u> s	<u>Total Weight</u>
.1- 100.0	787.0	18105.6
100.0- 300.0	132.0	22873.9
300.0- 500.0	44.0	17234.2
500.0- 600.0	5.0	2822.5
600.0- 700.0	10.0	6472.1
700.0- 800.0	7.0	5110.1
800.0- 900.0	6.0	4995.8
900.0-1000.0	4.0	3551.6
1000.0-1200.0	11.0	12167.4
1200.0-1400.0	6.0	7805.8
1400.0-1700.0	10.0	15196.2
1700.0-2000.0	7.0	12805.3
2000.0-2500.0	2.0	4234.0
2500.0-3000.0	4.0	10853.5
3000.0 +	6.0	23506.1

**FRAGMENT WEIGHT-PRESENTED AREA DATA
FOR TEST NO. QD-155-05**

Polar Zones 0°-180°

No. of Frags Selected for Measurements = 236

Frag Wt (Grains)	Minimum Area	Presented Area (in. ²)		Average Area	Gamma (in. ² /lb)	Maximum Area	Gamma (in. ² /lb)
		Gamma (in. ² /lb)					
5227.7	2.2805	3.05	3.2786	4.39	4.3005	5.76	
4377.5	2.0030	3.20	2.9724	4.75	3.8330	6.13	
4337.4	2.3830	3.85	3.0724	4.96	3.8530	6.22	
3311.3	2.1070	4.45	2.5501	5.39	3.0870	6.53	
2930.2	1.5800	3.77	2.3700	5.66	3.0700	7.33	
2780.5	1.6400	4.13	2.2781	5.74	2.8300	7.12	
2536.7	1.4185	3.91	2.0885	5.76	2.5885	7.14	
2606.1	1.6340	4.39	2.1459	5.76	2.6440	7.10	
3039.7	2.1600	4.97	2.6156	6.02	3.2000	7.37	
3212.5	1.9915	4.34	2.7953	6.09	3.5515	7.74	
1623.2	1.1110	4.79	1.5216	6.56	2.0210	8.72	
2228.1	1.6440	5.16	2.1209	6.66	2.5640	8.06	
2005.9	1.5865	5.54	1.9428	6.78	2.3765	8.29	
1867.0	1.1680	4.38	1.9111	7.17	2.3780	8.92	
1666.4	1.2155	5.11	1.7343	7.29	2.6855	11.28	
1609.3	1.4750	6.42	1.6794	7.30	2.0050	8.72	
1891.7	.9915	3.67	1.9890	7.36	3.5715	13.22	
1725.1	1.2655	5.14	1.8205	7.39	2.3455	9.52	
1779.1	1.3740	5.41	1.8871	7.43	2.3740	9.34	
1518.1	1.3850	6.39	1.6125	7.44	1.8250	8.42	
1425.8	1.0025	4.92	1.5231	7.48	2.2325	10.96	
1224.8	.8535	4.88	1.3235	7.56	1.7235	9.85	
1486.7	1.0010	4.71	1.6766	7.89	2.2110	10.41	
1056.8	.7525	4.98	1.2131	8.04	1.8625	12.34	
1911.8	1.8270	6.69	2.2283	8.16	2.6770	9.80	
1885.5	1.2660	4.70	2.2248	8.26	3.9160	14.54	
1459.3	1.3670	6.56	1.7326	8.31	2.1770	10.44	
1316.6	1.3350	7.10	1.5663	8.33	1.7650	9.38	
1494.6	.8180	3.83	1.7905	8.39	2.7480	12.87	
1745.1	1.2445	4.99	2.1058	8.45	2.9945	12.01	
1512.8	1.4055	6.50	1.8480	8.55	2.3255	10.76	
1076.3	1.0820	7.04	1.3339	8.68	1.5920	10.35	
1376.6	1.0040	5.11	1.7159	8.73	2.5940	13.19	
1128.0	1.1150	6.92	1.4219	8.88	1.7050	10.58	
1103.1	.9280	5.89	1.3924	8.84	1.9280	12.23	
1342.9	1.3125	6.84	1.6963	8.84	2.0625	10.75	
1187.1	.9295	5.48	1.5101	8.90	1.8195	10.73	
1182.4	.9955	5.89	1.5193	8.99	1.9555	11.58	
1056.1	.9750	6.46	1.3963	9.25	1.8950	12.56	
888.9	1.0360	8.16	1.1791	9.29	1.3360	10.52	
937.1	.8095	6.05	1.2439	9.29	1.8895	14.11	
1186.7	.7925	4.67	1.5756	9.29	2.2425	13.23	
1133.7	.9230	5.70	1.5299	9.45	2.3150	14.29	
1400.0	1.2445	6.22	1.9420	9.71	2.4545	12.27	
1250.1	.7040	3.94	1.7384	9.73	2.7340	15.31	
600.1	.5220	6.09	.8389	9.79	1.1520	13.44	
803.4	.7335	6.39	1.1410	9.94	1.5035	13.10	
962.3	1.0750	7.82	1.3763	10.01	1.8050	13.13	

**FRAGMENT WEIGHT-PRESENTED AREA DATA
FOR TEST NO. QD-155-05**

Polar Zones 0°-180°

No. of Frags Selected for Measurements = 236

Frag Wt (Grains)	Presented Area (in. ²)		Average Area	Gamma (in. ² /lb)	Maximum Area	Gamma (in. ² /lb)
	Minimum Area	Gamma (in. ² /lb)				
656.7	.6575	7.01	.9425	10.05	1.2975	13.83
777.2	.8320	7.49	1.1308	10.18	1.4420	12.99
815.5	.8035	6.90	1.1873	10.19	1.5635	13.42
711.1	.7605	7.49	1.0449	10.29	1.4205	13.98
451.3	.4130	6.41	.6667	10.34	1.0230	15.87
1043.6	.8985	6.03	1.5454	10.37	2.4485	16.42
618.2	.4835	5.47	.9291	10.52	1.4335	16.23
709.7	.6820	6.73	1.0689	10.54	1.5320	15.11
914.9	.9125	6.98	1.3913	10.64	2.1725	16.62
870.1	.9380	7.55	1.3311	10.71	1.8880	15.19
635.5	.7305	8.05	.9942	10.95	1.2105	13.33
583.4	.5975	7.17	.9131	10.96	1.1275	13.53
814.1	.6510	5.60	1.2854	11.05	2.1010	18.07
664.0	.6805	7.17	1.0499	11.07	1.3005	13.71
937.3	.7555	5.64	1.4824	11.07	2.2955	17.14
1294.8	1.0665	5.77	2.0521	11.09	3.3165	17.93
591.4	.4335	5.13	.9460	11.20	1.5735	18.62
739.3	.8665	8.20	1.2090	11.45	1.7465	16.54
554.0	.5320	6.72	.9095	11.49	1.1120	14.05
371.6	.3045	5.74	.6101	11.49	.8545	16.10
757.8	.8735	8.07	1.2473	11.52	1.5135	13.98
704.0	.6795	6.76	1.1614	11.55	1.8695	18.59
451.4	.4690	7.27	.7509	11.64	1.0790	16.73
656.5	.7090	7.56	1.0978	11.70	1.3990	14.92
622.4	.6335	7.12	1.0429	11.73	1.4835	16.68
647.5	.8128	8.79	1.0990	11.88	1.5028	16.25
676.6	.6295	6.51	1.1745	12.15	1.8095	18.72
711.0	.7980	7.86	1.2486	12.29	1.8180	17.90
694.6	.7750	7.81	1.2263	12.36	1.7250	17.38
803.8	.8065	7.02	1.4259	12.42	1.9165	16.69
528.7	.4235	5.61	1.0085	13.35	1.2735	16.86
462.0	.4750	7.20	.8844	13.40	1.3150	19.92
565.0	.5365	6.65	1.0834	13.42	1.7865	22.13
205.4	.2900	9.88	.4263	14.53	.6000	20.45
162.8	.1685	7.25	.3723	16.01	.6885	29.60
1013.6	1.9510	13.47	2.4016	16.59	2.6110	18.03
146.9	.1940	9.24	.4084	19.46	.6040	28.78
159.6	.3040	13.33	.4790	21.01	.7140	31.32
137.2	.5405	27.58	.9767	49.83	1.5905	81.15

FRAGMENT HAZARD INVESTIGATION

Test Number: QD-155-09

Item Tested: M107 155mm projectile containing 15 lb of TNT explosive and equipped with a modified M564 Nose Fuze assembled with a Hercules Special Blasting Cap.

Number of Firings and Dates: 1 - 20 April 1976
1 - 21 April 1976
1 - 22 April 1976

Number of Items per Firing: 2

Location of Test: NSWC/DL - Experimental Explosive Area

Arena Configuration: Azimuthal Arena

Fragment Recovery - 85° to 100° polar
0° to 135° azimuthal

Fragment Velocities - 80° to 105° polar
180° to 360° azimuthal

Projectile Orientation: Two 155mm projectiles, vertically positioned side by side with centerlines seven inches apart.

Meteorology:

20 April 1976	Barometric Pressure	- 30.01 in. Hg.
	Temperature	- 93°F
21 April 1976	Barometric Pressure	- 30.00 in. Hg.
	Temperature	- 90°F
22 April 1976	Barometric Pressure	- 28.95 in. Hg.
	Temperature	- 85°F

Instrumentation: Fragment Velocity - Five high speed motion picture cameras; black and white film

Post Test Comments: Fragment concentrations are varying in the azimuthal direction for all three arena firings. A well defined fragment concentration was evident in the second arena firing at the 280° azimuthal location.

**AVERAGE FRAGMENT VELOCITIES PER AZIMUTHAL ZONE
FOR EACH POLAR ZONE OF TEST NO. QD-155-09**

THREE ARENA FIRINGS

ZONE (DEG) POLAR

AZIMUTHAL	Velocity (ft/s)*				
	<u>80-85</u>	<u>85-90</u>	<u>90-95</u>	<u>95-100</u>	<u>100-105</u>
360-350	3799.5	4066.3	4573.1	4025.6	4032.3
350-340	4266.3	4262.7	4328.5	4246.8	3904.4
340-330	4011.4	4145.3	4353.1	4234.1	4017.8
330-320	4011.1	4236.8	4351.8	4310.4	3866.9
320-310	3820.2	4222.2	4437.5	4151.8	3864.6
310-300	3897.2	4254.5	4537.2	4386.1	3710.2
300-290	4184.2	4495.9	4572.6	4506.2	4058.6
390-280	4885.8	4956.5	5237.6	5473.2	4983.7
280-270	5490.7	5241.8	5572.1	5245.8	4746.4
270-260	3489.1	4013.7	4289.7	4097.6	3801.2
260-250	3874.9	4266.4	4236.5	4015.6	3806.3
250-240	4784.4	4427.0	4439.9	4383.3	4182.0
240-230	4220.1	4251.6	4170.7	4392.6	3837.1
230-220	3846.1	3892.1	4135.1	3970.2	3611.4
220-210	3794.0	4021.0	4209.2	3857.6	3533.9
210-200	3743.8	3907.5	4156.6	3959.6	**
200-190	3836.4	4003.9	4266.2	4075.0	**
190-180	3957.4	4075.5	4057.4	4043.2	**

*Velocities recorded at 25.0 ft stand-off
**Instrumentation failure

**AVERAGE FRAGMENT HIT DATA ON WITNESS PANELS PER AZIMUTHAL ZONE
FOR EACH POLAR ZONE OF TEST NO. QD-155-09**

THREE ARENA FIRINGS

ZONE (DEG) POLAR

AZIMUTHAL	NO. FRAG HITS				
	<u>80-85</u>	<u>85-90</u>	<u>90-95</u>	<u>95-100</u>	<u>100-105</u>
360-350	5	5	8	11	10
350-340	5	5	5	11	8
340-330	4	6	9	10	10
330-320	6	7	5	11	12
320-310	8	8	11	15	17
310-300	15	21	21	37	41
300-290	28	46	49	44	46
290-280	24	30	39	52	59
280-270	34	85	71	45	69
270-260	15	11	18	22	25
260-250	15	21	20	22	24
250-240	22	32	19	23	26
240-230	10	11	8	15	17
230-220	9	8	5	10	10
220-210	5	6	8	10	9
210-200	7	9	7	12	9
200-190	6	6	5	10	10
190-180	8	7	3	9	9

FRAGMENT RECOVERY DATA FOR TEST NO. QD-155-09 (FRAGMENT WEIGHT AND NUMBER TOTALS)

THREE ARENA FIRINGS

ZONE (DEG) POLAR				85-90		90-95		95-100	
AZIMUTHAL	FRAG NO.	FRAG WT. (GRAINS)	AVG. WT.	FRAG NO.	FRAG WT. (GRAINS)	AVG. WT.	FRAG NO.	FRAG WT. (GRAINS)	AVG. WT.
0-10	55.0	22171.1	403.1	30.0	5289.2	176.3	32.0	3718.3	116.2
10-20	28.0	2665.1	95.2	25.0	6137.5	245.5	29.0	11971.3	412.8
20-30	39.0	2332.1	59.8	14.0	1619.5	115.7	38.0	5063.8	133.3
30-40	26.0	4810.3	185.0	23.0	5515.6	239.8	36.0	12502.8	347.3
40-50	20.0	2090.6	104.5	33.0	3473.3	105.3	54.0	5989.5	110.9
50-60	60.0	7871.0	131.2	43.0	2631.8	61.2	73.0	18063.1	247.4
60-70	18.0	1938.9	107.7	22.0	6425.0	292.0	28.0	2022.3	72.2
70-80	0.0	*	*	125.0	31106.4	248.9	*	*	*
80-90	0.0	*	*	93.0	45812.5	492.6	*	*	*
90-100	37.0	18316.9	495.1	32.0	3461.2	108.2	55.0	8774.9	159.5
100-110	40.0	7931.0	198.3	32.0	7579.1	236.8	51.0	10901.9	213.8
110-120	64.0	8097.5	126.5	55.0	4237.5	77.0	70.0	10069.3	143.8
120-130	60.0	6467.0	107.8	77.0	7702.8	100.0	58.0	5315.8	91.7
130-135	2.0	32.3	16.2	21.0	7875.5	375.0	37.0	8147.0	220.2

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*These data are included in polar zone 90-95, due to celotex damage

FRAGMENT HAZARD INVESTIGATION

Test Number: QD-155-10

Item Tested: M107 155mm Projectile containing 15 lb of TNT explosive and equipped with a modified M564 Nose Fuze assembled with a Hercules Special Blasting Cap.

Number of Firings and Dates: 1 - 21 May 1976
1 - 25 May 1976
1 - 27 May 1976

Number of Items per Firing: 4

Location of Test: NSWC/DL - Experimental Explosive Area

Arena Configuration: Azimuthal Arena

Fragment Recovery - 85° to 100° polar
20° to 140° azimuthal

Fragment Velocities - 80° to 105° polar
20° to 200° azimuthal

Projectile Orientation: Four 155mm projectiles vertically positioned with all centerlines seven inches apart forming a cube.

Meteorology:

21 May 1976	Barometric Pressure	- 29.81 in. Hg
	Temperature	80°F
25 May 1976	Barometric Pressure	- 80.01 in. Hg
	Temperature	78°F
27 May 1976	Barometric Pressure	- 29.51 in. Hg
	Temperature	81°F

Instrumentation: Fragment Velocity - Five high speed motion picture cameras with black & white film.

Documentation - One high speed motion picture camera with black & white film.

Post Test Comments: **FIRST FIRING:** Fragment jets formed at 280° and 330° azimuthal angles.

SECOND FIRING: Fragment jets formed at 280° and 330° azimuthal angles. Fragment jet was captured in the Celotex at the 180° azimuthal angle.

THIRD FIRING: Fragment jets did not form as in first two firings.

**AVERAGE FRAGMENT VELOCITIES PER AZIMUTHAL ZONE
FOR EACH POLAR ZONE OF TEST NO. QD-155-10**

THREE ARENA FIRINGS

ZONE (DEG) POLAR

AZIMUTHAL	Velocity (ft/s)*				
	<u>80-85</u>	<u>85-90</u>	<u>90-95</u>	<u>95-100</u>	<u>100-105</u>
380-370	3789.8	4701.6	4181.1	3814.5	3575.8
370-360	3636.8	4345.5	4088.5	3761.5	3470.8
360-350	4144.4	4754.2	4454.3	4231.1	3784.6
350-340	4713.7	5482.5	4858.6	4592.0	4618.3
340-330	5062.4	6363.5	5839.9	4844.7	5544.5
330-320	5351.8	5937.9	5738.8	5154.8	5543.8
320-310	4779.1	5451.6	5254.4	4850.7	5251.9
310-300	4601.9	5292.9	5124.6	4964.4	3943.0
300-290	4606.4	5157.0	5200.1	5377.3	4246.6
290-280	6055.9	5973.7	6120.1	6356.8	6089.5
280-270	6299.2	6464.1	6451.0	6341.6	6492.3
270-260	5914.2	5949.4	5865.1	5184.7	4958.0
260-250	4205.7	4363.4	3954.9	3887.9	3607.2
250-240	3900.4	3958.4	3766.7	3717.9	3241.6
240-230	3607.0	3789.0	4151.6	4063.1	3807.8
230-220	3877.4	4022.1	4171.3	3994.2	3247.8
220-210	3800.6	4036.3	4177.1	3947.4	3414.2
210-200	4223.9	4288.0	4824.9	4247.9	4842.2

*Velocities recorded at 25.0 ft stand-off

**AVERAGE FRAGMENT VELOCITIES PER AZIMUTHAL ZONE
FOR EACH POLAR ZONE OF TEST NO. QD-155-10**

THREE ARENA FIRINGS

ZONE (DEG) POLAR

AZIMUTHAL	NO. FRAG HITS				
	<u>80-85</u>	<u>85-90</u>	<u>90-95</u>	<u>95-100</u>	<u>100-105</u>
380-370	15	21	25	33	41
370-360	16	17	22	29	31
360-350	14	18	28	40	36
350-340	24	33	43	46	51
340-330	37	35	32	35	45
330-320	30	26	33	27	25
320-310	11	16	18	15	20
310-300	8	15	16	21	23
300-290	18	29	29	34	33
290-280	66	74	93	92	105
280-270	49	66	57	66	57
270-260	15	16	24	30	35
260-250	11	17	17	28	25
250-240	20	30	20	21	28
240-230	17	21	21	16	29
230-220	8	12	9	12	11
220-210	8	11	12	18	16
210-200	16	23	16	18	16

FRAGMENT RECOVERY DATA FOR TEST NO. QD-155-10 (FRAGMENT WEIGHT AND NUMBER TOTALS)

THREE ARENA FIRINGS

ZONE (DEG) POLAR

85-90

90-95

95-100

AZIMUTHAL	FRAG NO.	FRAG WT. (GRAINS)	AVG. WT.	FRAG NO.	FRAG WT. (GRAINS)	AVG. WT.	FRAG NO.	FRAG WT. (GRAINS)	AVG. WT.
*20-30	68.0	14305.8	210.4	79.0	7724.5	97.8	85.0	13589.9	159.9
30-40	82.0	7015.6	85.6	86.0	8265.3	96.1	85.0	19257.6	226.6
40-50	59.0	5228.0	88.6	71.0	8378.3	118.0	84.0	17425.2	207.4
50-60	106.0	8423.2	79.5	64.0	8788.5	137.3	75.0	10485.5	139.8
60-70	149.0	12017.0	80.7	118.0	21377.1	181.2	141.0	71060.9	504.0
70-80	132.0	25386.6	192.3	186.0	58739.2	315.8	212.0	29215.6	137.8
80-90	73.0	9763.6	133.7	77.0	18918.1	245.7	64.0	36969.8	577.7
90-100	76.0	8577.5	112.9	86.0	17600.9	204.7	101.0	33734.1	334.0
100-110	96.0	9247.1	96.3	138.0	13370.1	96.9	178.0	45089.0	253.3
110-120	80.0	6573.8	82.2	61.0	6219.2	102.0	82.0	17570.5	214.3
120-130	74.0	7770.6	105.0	33.0	7246.0	219.6	83.0	12060.7	145.3
130-140	117.0	27097.7	231.6	88.0	29930.9	340.1	70.0	21491.0	307.0
**170-180	65.0	8376.8	128.9	84.0	5711.1	68.0	63.0	14368.3	228.1
180-190	69.0	9421.2	136.5	68.0	10456.1	153.8	93.0	13835.3	148.8
***170-180	49.0	2126.6	43.4	66.0	4592.6	69.6	80.0	6645.1	83.1
180-190	28.0	4061.0	145.0	15.0	1454.0	96.9	40.0	12760.3	319.0

*Zones 20-140, three arena firings
 **Zones 170-180, 2nd arena firing
 ***Zones 170-180, 3rd arena firing

FRAGMENT HAZARD INVESTIGATION

Test Number: QD-155-12

Item Tested: M107 155mm Projectile containing 15 lb of TNT explosive and equipped with a modified M564 Nose Fuze.

Number of Firings and Dates: 1 - 8 July 1976
1 - 19 July 1976

Number of Items per Firing: 8

Location of Test: NSWC/DL - Experimental Explosive Area

Arena Configuration: Azimuthal

Fragment Recovery - 90° to 100° polar
140° to 340° azimuthal

Fragment Velocities - 80° to 105° polar
160° to 340° azimuthal

Projectile Orientation: Two vertical rows of four projectiles in a pallet with all center-lines seven inches apart.

Meteorology:

8 July 1976	Barometric Pressure	- 29.95 in. Hg
	Temperature	- 87°F
19 July 1976	Barometric Pressure	- 30.95 in. Hg
	Temperature	- 90°F

Instrumentation: Fragment Velocity - Five high speed motion picture cameras with black & white film.

Documentation - Two high speed motion picture cameras (one with color film)

Post Test Comments: Well defined fragment concentrations formed as desired for both arena firings.

A collection of large ground fragments was conducted.

**AVERAGE FRAGMENT VELOCITIES PER AZIMUTHAL ZONE
FOR EACH POLAR ZONE OF TEST NO. QD-155-12**

THREE ARENA FIRINGS

ZONE (DEG) POLAR

AZIMUTHAL	Velocity (ft/s)*				
	<u>80-85</u>	<u>85-90</u>	<u>90-95</u>	<u>95-100</u>	<u>100-105</u>
340-330	4143.0	4121.9	4034.4	4127.8	3676.5
330-320	3974.6	4123.5	4278.1	3867.6	3817.7
320-310	3900.0	4056.5	4205.5	4076.2	3751.5
310-300	3945.3	4134.2	4140.2	4078.6	3840.0
300-290	3954.9	4201.5	4244.8	4186.5	3741.1
290-280	4523.5	4193.0	4740.5	4092.8	0.0
280-270	6869.6	7659.5	7800.2	8057.7	8045.3
270-260	6786.5	7386.6	7557.6	7132.7	7395.5
260-250	5568.7	4956.3	5182.6	4380.5	4326.9
250-240	4032.0	4211.6	4214.3	4228.3	4060.3
240-230	4098.4	4167.3	4191.0	4178.4	4807.7
230-220	4314.6	4098.4	4185.3	4098.4	4074.3
220-210	4125.4	4232.6	4217.5	4154.3	0.0
210-200	3966.5	4065.3	4290.0	4256.0	3924.5
200-190	4526.4	4298.3	4198.4	4406.1	4132.2
190-180	6741.2	7208.6	8026.9	8675.4	8293.4
180-170	6675.9	7426.5	7447.5	7919.8	8323.0
170-160	4347.8	4554.9	4520.1	4226.6	4167.0

*Velocity data recorded at 25.0 ft stand-off

**AVERAGE FRAGMENT HIT DATA ON WITNESS PANELS PER AZIMUTHAL ZONE
FOR EACH POLAR ZONE OF TEST NO. QD-155-12**

THREE ARENA FIRINGS

ZONE (DEG) POLAR

AZIMUTHAL	No. of Frag. Hits				
	<u>80-85</u>	<u>85-90</u>	<u>90-95</u>	<u>95-100</u>	<u>100-105</u>
340-330	4	4	5	12	9
330-320	5	3	8	10	7
320-310	5	4	8	10	8
310-300	5	6	7	7	6
300-290	7	4	7	5	10
290-280	40	23	20	19	17
280-270	111	252	291	299	300
270-260	132	165	206	204	213
260-250	28	20	36	24	20
250-240	5	7	5	9	10
240-230	6	4	4	12	8
230-220	5	2	5	5	12
220-210	2	4	6	6	10
210-200	2	6	7	10	10
200-190	5	6	5	11	10
290-180	88	112	179	181	192
180-170	57	61	70	59	62
170-160	4	4	5	7	6

FRAGMENT RECOVERY DATA FOR TEST NO. QD-155-12 (FIRST FIRING)
(FRAGMENT WEIGHT AND NUMBER TOTALS)

ARENA FIRING NO. 1

ZONE (DEG) POLAR

90-95

95-100

AZIMUTHAL	Frag No.	Frag Wt. (Grains)	Avg. Wt.	Frag No.	Frag Wt. (Grains)	Avg. Wt.
340-350	36.0	339.6	9.4	49.0	5338.0	108.9
350-360	62.0	7922.6	127.8	86.0	17945.9	208.7
0- 10	37.0	2042.9	55.2	56.0	12266.7	219.0
10- 20	13.0	1560.7	120.1	13.0	4489.6	345.4
20- 30	18.0	4410.9	245.1	24.0	6257.1	260.7
30- 40	22.0	1610.9	73.2	23.0	3936.9	171.2
40- 50	13.0	1766.5	135.9	15.0	2834.8	189.0
50- 60	13.0	3214.7	247.3	13.0	5238.5	403.0
60- 70	25.0	3217.9	128.7	22.0	4341.4	197.3
70- 80	90.0	6792.4	75.5	92.0	17958.7	195.2
80- 90	156.0	26505.0	169.9	264.0	79514.1	301.2
90-100	194.0	17045.5	87.9	222.0	35730.9	161.0
100-110	39.0	5202.8	133.4	41.0	5735.2	139.9
110-120	29.0	2782.6	96.0	22.0	3606.7	163.9
120-130	18.0	2335.6	129.8	16.0	2256.7	141.0
130-140	19.0	1419.3	74.7	12.0	7069.4	589.1

**FRAGMENT WEIGHT-PRESENTED AREA DATA
FOR THE PROJECTILE INTERACTION AREA**

ARENA FIRING NO. 1

INTERACTION AREA 0 DEGREES AZIMUTHALLY

POLAR ZONE 90-95

NO. FRAGS SELECTED FOR MEASUREMENTS = 7

Frag Wt. (Grains)	Minimum Area	Gamma (sq. in./lb)	Presented Area (Sq. In.)		Maximum Area	Gamma (sq. in./lb)
			Average Area	Gamma (sq. in./lb)		
527.7	.3935	5.22	.7929	10.52	1.1935	15.83
620.6	.4895	5.52	1.0570	11.92	1.6795	18.94
597.3	.5850	6.86	1.0194	11.95	1.5750	18.46
1865.5	.4500	1.69	3.4750	13.04	6.0000	22.51
821.9	.8455	7.20	1.5418	13.13	2.3955	20.40
1027.3	.6860	4.67	1.9291	13.15	3.3460	22.80
706.1	.7815	7.75	1.5140	15.01	2.3715	23.51

**FRAGMENT WEIGHT-PRESENTED AREA DATA
FOR THE PROJECTILE INTERACTION AREA**

ARENA FIRING NO. 1

INTERACTION AREA 0 DEGREES AZIMUTHALLY

POLAR ZONE 95-100

NO. FRAGS SELECTED FOR MEASUREMENTS = 16

Frag Wt. Grains)	Minimum Area	Gamma (sq. in./lb)	Presented Area (Sq. In.)		Maximum Area	Gamma (sq. in./lb)
			Average Area	Gamma (sq. in./lb)		
2266.7	1.4000	4.32	2.3600	7.29	3.5100	10.84
1691.1	1.0955	4.53	1.8205	7.54	2.5255	10.45
1783.7	1.2815	5.03	1.9615	7.70	2.7615	10.84
1533.0	1.0070	4.60	1.8176	8.30	2.3370	10.67
1885.5	1.0160	3.77	2.2735	8.44	3.8360	14.24
1323.6	.7365	3.90	1.6034	8.48	2.2765	12.04
1910.2	1.0820	3.97	2.4483	8.97	3.9120	14.34
773.4	.5320	4.82	1.1245	10.18	1.6920	15.31
521.4	.4945	6.64	.7882	10.58	1.1645	15.63
511.2	.4015	5.62	.7967	10.91	1.1205	15.34
2036.8	.3000	1.03	3.3125	11.38	5.4000	18.56
913.1	.7670	5.88	1.6851	12.92	2.8870	22.13
726.4	.7350	7.08	1.3481	12.99	2.1150	20.38
686.2	.6740	6.88	1.2990	13.25	1.6640	16.97
863.5	.8725	7.07	1.6863	13.67	2.6925	21.83
925.4	.9770	7.39	1.9426	14.69	3.0070	22.75

**FRAGMENT WEIGHT-PRESENTED AREA DATA
FOR THE PROJECTILE INTERACTION AREA**

ARENA FIRING NO. 1

INTERACTION AREA 90 DEGREES AZIMUTHALLY

POLAR ZONE 90-95

NO. FRAGS SELECTED FOR MEASUREMENTS = 23

<u>Frag Wt (Grains)</u>	<u>Minimum Area</u>	<u>Gamma (in.²/lb)</u>	<u>Average Area</u>	<u>Gamma (in.²/lb)</u>	<u>Maximum Area</u>	<u>Gamma (in.²/lb)</u>
6435.9	.6000	.65	5.7312	6.23	11.8500	12.89
1080.9	.6935	4.49	1.2460	8.07	1.9335	12.52
1292.4	1.0320	5.59	1.5039	8.15	2.0920	11.33
693.5	.5045	5.09	.9432	9.52	1.3645	13.77
892.3	.2000	1.57	1.2500	9.81	2.3000	18.04
670.3	.5175	5.40	.9819	10.25	1.5475	16.16
849.8	.6475	5.33	1.2481	10.28	1.7875	14.72
1238.1	.8320	4.70	1.9283	10.90	3.1520	17.82
1013.5	.9205	6.35	1.5961	11.00	2.4005	16.55
546.5	.3475	4.45	.8637	11.06	1.1575	14.83
688.7	.1825	1.85	1.0969	11.15	2.1725	22.08
704.1	.7575	7.53	1.1469	11.40	1.6075	15.98
793.7	.5650	4.98	1.3194	11.64	2.2850	20.15
891.0	.6585	5.17	1.4873	11.68	2.3485	18.45
506.5	.3705	5.12	.8986	12.42	1.1905	16.45
671.3	.6150	6.41	1.1931	12.44	1.8250	19.03
739.0	.7340	6.95	1.3378	12.67	2.0740	19.65
742.8	.8315	7.84	1.5315	14.43	2.4215	22.82
1227.7	.3500	2.00	2.6188	14.93	3.7000	21.10
568.4	.6295	7.75	1.2189	15.01	2.0195	24.87
603.3	.5470	6.35	1.3370	15.51	2.3470	27.23
645.3	.1000	1.08	1.4625	15.86	2.3000	24.95
1580.1	3.0000	13.29	4.2375	18.77	5.4500	24.14

**FRAGMENT WEIGHT-PRESENTED AREA DATA
FOR THE PROJECTILE INTERACTION AREA**

ARENA FIRING NO. 1

INTERACTION AREA 90 DEGREES AZIMUTHALLY

POLAR ZONE 95-100

NO. FRAGS SELECTED FOR MEASUREMENTS = 70

<u>Frag Wt (Grains)</u>	<u>Minimum Area</u>	<u>Gamma (in.²/lb)</u>	<u>Average Area</u>	<u>Gamma (in.²/lb)</u>	<u>Maximum Area</u>	<u>Gamma (in.²/lb)</u>
4558.0	1.1500	1.77	3.6531	5.61	5.1000	7.83
2917.8	.8500	2.04	2.8188	6.76	3.9000	9.36
2774.3	.2000	.50	2.6813	6.77	3.8000	9.59
1503.3	.8475	3.95	1.5194	7.07	2.1175	9.86
1369.7	.7350	3.76	1.3950	7.13	2.0750	10.60
2149.4	.9000	2.93	2.2000	7.16	3.2000	10.42
1575.8	1.0020	4.45	1.6370	7.27	2.3220	10.31
2218.8	.4000	1.26	2.4250	7.65	3.5000	11.04
2576.8	.4000	1.09	2.9063	7.89	4.4000	11.95
2481.1	1.7150	4.84	2.8919	8.16	4.7450	13.39
1624.8	.8130	3.50	1.9055	8.21	3.1330	13.50
1502.6	.9480	4.42	1.7718	8.25	2.8580	13.31
1336.8	.8865	4.64	1.5871	8.31	2.0965	10.98
1426.6	.9715	4.77	1.7734	8.51	2.6315	12.91
1365.9	1.0400	5.33	1.6806	8.61	2.4300	12.45
1461.1	.8725	4.18	1.8600	8.91	2.8825	13.81
670.4	.4275	4.46	.8662	9.04	1.3075	13.65
995.8	.2000	1.41	1.2875	9.05	2.2000	15.46
731.1	.5175	4.95	.9456	9.05	1.5075	14.43
946.1	.7550	5.59	1.2431	9.20	1.7050	12.61
632.3	.3975	4.40	.8319	9.21	1.1375	12.59
4397.6	.6000	.96	5.9481	9.47	9.4000	14.96
569.3	.5585	6.87	.7766	9.55	.9285	11.42
961.1	.7650	5.57	1.3463	9.81	1.7550	12.78
958.0	.7320	5.35	1.3445	9.82	2.2620	16.53
2266.7	.5500	1.70	3.1875	9.84	5.4000	16.68
823.7	.6635	5.64	1.1585	9.85	1.7735	15.07
996.1	.7950	5.59	1.4075	9.89	2.2050	15.50
767.6	.6120	5.58	1.0895	9.94	1.6320	14.88
596.2	.4590	5.39	.8465	9.94	1.2290	14.43
1582.5	.3000	1.33	2.2500	9.95	3.4000	15.04
633.8	.4860	5.37	.9229	10.19	1.3060	14.42
866.5	.5065	4.09	1.2646	10.22	2.0165	16.29
779.9	.6450	5.79	1.1538	10.36	1.6050	14.41
1044.2	.9755	6.54	1.5474	10.37	2.2755	15.25
720.9	.5615	5.45	1.0715	10.40	1.5015	14.58
1122.1	.5240	3.89	1.7009	10.61	2.9840	18.62
733.2	.1625	1.55	1.1213	10.70	1.6125	15.39
651.8	.5805	6.23	1.0049	10.79	1.4605	15.69
559.5	.5305	6.64	.8630	10.80	1.3205	16.52
1264.0	1.1000	.55	1.9875	10.84	3.5000	19.08
1458.5	1.1475	5.51	2.2744	10.92	3.8575	18.51
1811.5	1.5180	5.87	2.8386	10.97	4.6480	17.96
552.9	.5290	6.70	.8684	10.99	1.3290	16.83
620.2	.6405	7.23	.9999	11.29	1.4305	16.15

**FRAGMENT WEIGHT-PRESENTED AREA DATA
FOR THE PROJECTILE INTERACTION AREA**

ARENA FIRING NO. 1

INTERACTION AREA 90 DEGREES AZIMUTHALLY

POLAR ZONE 95-100

NO. FRAGS SELECTED FOR MEASUREMENTS = 70

<u>Frag Wt (Grains)</u>	<u>Minimum Area</u>	<u>Gamma (in.²/lb)</u>	<u>Average Area</u>	<u>Gamma (in.²/lb)</u>	<u>Maximum Area</u>	<u>Gamma (in.²/lb)</u>
716.8	.4335	4.23	1.1729	11.45	1.6435	16.05
650.2	.4525	4.87	1.0688	11.51	1.7225	18.54
775.4	.5980	5.40	1.2849	11.60	2.138-	19.30
876.2	.5555	4.44	1.4536	11.61	2.6855	21.45
757.2	.3410	3.15	1.2610	11.66	2.2210	20.53
567.0	.5175	6.39	.9444	11.66	1.2775	15.77
538.0	.4220	5.49	.8976	11.68	1.2020	15.64
646.5	.6405	6.94	1.0893	11.79	1.5905	17.22
592.0	.5090	6.02	1.0153	12.00	1.5590	18.43
810.3	.5185	4.48	1.3904	12.01	2.6685	23.05
690.6	.6405	6.49	1.1899	12.06	1.7105	17.34
516.0	.4245	5.76	.8914	12.09	2.1545	29.23
700.9	.6080	6.07	1.2136	12.12	1.8980	18.96
725.0	.8530	8.24	1.2686	12.25	1.8030	17.41
615.2	.5605	6.38	1.0880	12.38	1.7205	19.58
1171.8	1.0785	6.44	2.0735	12.39	3.3485	20.00
605.7	.6280	7.26	1.0936	12.64	1.4980	17.31
898.4	.6340	4.94	1.6665	12.98	3.0340	23.64
503.3	.4235	5.89	.9391	13.06	1.5735	21.88
679.9	.5025	5.17	1.3063	13.45	2.2825	23.50
1425.9	.3000	1.47	2.7875	13.68	5.1000	25.04
544.9	.6380	8.20	1.1699	15.03	1.6480	21.17
633.2	.7045	7.79	1.4239	15.74	2.2445	24.81
922.0	.1000	.76	2.2025	16.72	3.6000	27.33
238.3	.4500	13.22	2.2125	64.99	3.8000	111.62

FRAGMENT RECOVERY DATA FOR TEST NO. QD-155-12 (SECOND FIRING)
(FRAGMENT WEIGHT AND NUMBER TOTALS)

ARENA FIRING NO. 2

ZONE (DEG) POLAR

90-95

95-100

AZIMUTHAL	Frag	Frag	Avg.	Frag	Frag	Avg.
	No.	Wt. (Grains)	Wt.	No.	Wt. (Grains)	Wt.
340-350	14.0	425.2	30.4	34.0	3600.3	105.9
350-360	70.0	7132.8	101.9	117.0	12241.7	104.6
0- 10	194.0	21443.9	110.5	222.0	43219.9	194.7
10- 20	31.0	472.8	15.3	37.0	4614.5	124.7
20- 30	13.0	882.8	67.9	22.0	1824.6	82.9
30- 40	24.0	1675.7	69.8	23.0	4825.4	209.8
40- 50	10.0	729.3	72.9	12.0	3139.8	261.7
50- 60	23.0	5151.9	224.0	18.0	4544.8	252.5
60- 70	12.0	2866.6	238.9	29.0	5575.5	192.3
70- 80	24.0	5357.3	223.2	36.0	5954.4	165.4
80- 90	90.0	12406.4	137.8	129.0	26008.0	201.6
90-100	321.0	39219.6	122.2	492.0	104200.6	211.8
100-110	47.0	7501.7	159.6	60.0	13355.7	222.6
110-120	22.0	805.6	36.6	18.0	2537.5	141.0
120-130	20.0	2408.5	120.4	17.0	5892.1	346.6
130-140	18.0	1822.7	101.3	23.0	3432.1	149.2

**FRAGMENT WEIGHT-PRESENTED AREA DATA
FOR THE PROJECTILE INTERACTION AREA**

ARENA FIRING NO. 2

INTERACTION AREA 0 DEGREES AZIMUTHALLY

POLAR ZONE 90-95

NO. FRAGS SELECTED FOR MEASUREMENTS = 16

<u>Frag Wt (Grains)</u>	<u>Minimum Area</u>	<u>Gamma (in.²/lb)</u>	<u>Average Area</u>	<u>Gamma (in.²/lb)</u>	<u>Maximum Area</u>	<u>Gamma (in.²/lb)</u>
1135.2	.8435	5.20	1.3510	8.33	1.7635	10.87
2325.3	.8000	2.41	2.8438	8.56	5.0000	15.05
650.0	.5215	5.62	.8190	8.82	1.0215	11.00
1367.6	.3000	1.54	1.7831	9.13	3.1100	15.92
689.9	.3760	3.82	.9491	9.63	1.2260	12.44
1242.5	.7935	4.47	1.7441	9.83	2.8935	16.30
616.8	.3820	4.34	.8820	10.01	1.3720	15.57
1160.0	.1900	1.15	1.8419	11.11	3.3000	19.91
501.1	.4445	6.21	.7976	11.14	1.1845	16.55
811.3	.6310	5.44	1.3060	11.27	2.1010	18.13
1596.4	.2500	1.10	2.5888	11.35	4.9000	21.49
2570.6	1.1000	3.00	4.1875	11.40	6.8000	18.52
565.6	.4835	5.98	.9804	12.13	1.5135	18.73
578.6	.5920	7.16	1.0858	13.14	1.7620	21.32
680.8	.5965	6.13	1.3290	13.66	2.3065	23.72
1617.1	1.8000	7.79	3.7663	16.30	6.4000	27.70

**FRAGMENT WEIGHT-PRESENTED AREA DATA
FOR THE PROJECTILE INTERACTION AREA**

ARENA FIRING NO. 2

INTERACTION AREA 0 DEGREES AZIMUTHALLY

POLAR ZONE 95-100

NO. FRAGS SELECTED FOR MEASUREMENTS = 33

<u>Frag Wt (Grains)</u>	<u>Minimum Area</u>	<u>Gamma (in.²/lb)</u>	<u>Average Area</u>	<u>Gamma (in.²/lb)</u>	<u>Maximum Area</u>	<u>Gamma (in.²/lb)</u>
3430.1	1.4000	2.86	3.1250	6.38	4.6000	9.39
3450.1	1.4000	2.84	3.2125	6.52	5.5000	11.16
2356.2	.2500	.74	2.3969	7.12	4.5500	13.52
1277.0	.7680	4.21	1.3524	7.41	1.8880	10.35
1342.9	.7950	4.14	1.4481	7.55	2.0150	10.50
1007.3	.6590	4.58	1.0890	7.57	1.6890	11.74
942.6	.5880	4.37	1.1074	8.22	1.5380	11.42
703.7	.4175	4.15	.8606	8.56	1.3275	13.21
1533.6	.3000	1.37	1.9019	8.68	3.1000	14.15
1119.8	.7610	4.76	1.1010	9.32	2.3210	14.51
712.0	.3975	3.91	.9494	9.33	1.3075	12.85
589.2	.3945	4.69	.7882	9.36	1.1345	13.48
579.2	.3945	4.77	.7914	9.56	1.1645	14.07
769.3	.5410	4.92	1.0741	9.77	1.5410	14.02
815.5	.7295	6.26	1.1476	9.85	1.7395	14.93
981.2	.4240	3.02	1.4221	10.15	2.2040	15.72
609.0	.4845	5.57	.9114	10.48	1.2645	14.53
3106.1	1.2000	2.70	4.6500	10.48	8.2000	18.48
638.8	.5450	5.97	.9669	10.60	1.3850	15.18
672.0	.5595	5.83	1.0233	10.66	1.6295	16.97
669.1	.5720	5.98	1.0401	10.88	1.8420	19.27
669.6	.4365	4.56	1.0484	10.96	1.5165	15.85
525.6	.4460	5.94	.8235	10.97	1.1360	15.13
766.6	.6610	6.04	1.2391	11.31	1.9910	18.18
598.5	.4150	4.85	.9775	11.43	1.4350	16.78
1179.1	.1000	.59	1.9594	11.63	3.5000	20.78
636.2	.4295	4.73	1.1070	12.18	1.5895	17.49
590.2	.5405	6.41	1.0599	12.57	1.3005	15.42
889.3	.6030	4.75	1.6011	12.60	2.8230	22.22
799.5	.7170	6.28	1.4401	12.61	2.5570	22.39
747.7	.4840	4.53	1.3471	12.61	2.3040	21.57
802.8	.2000	1.74	1.5206	13.26	2.6500	23.11
1485.1	1.6000	7.54	3.1500	14.85	5.0000	23.57

**FRAGMENT WEIGHT-PRESENTED AREA DATA
FOR THE PROJECTILE INTERACTION AREA**

ARENA FIRING NO. 2

INTERACTION AREA 90 DEGREES AZIMUTHALLY

POLAR ZONE 90-95

NO. FRAGS SELECTED FOR MEASUREMENTS = 34

<u>Frag Wt</u> <u>(Grains)</u>	<u>Minimum</u> <u>Area</u>	<u>Gamma</u> <u>(in.²/lb)</u>	<u>Average</u> <u>Area</u>	<u>Gamma</u> <u>(in.²/lb)</u>	<u>Maximum</u> <u>Area</u>	<u>Gamma</u> <u>(in.²/lb)</u>
2024.4	.9410	3.25	1.6754	5.79	2.1510	7.44
1698.8	1.0865	4.48	1.7534	7.22	2.1565	8.89
1151.2	.2000	1.22	1.2938	7.87	3.2500	19.76
2464.2	.4000	1.14	2.8313	8.04	4.9000	13.92
775.2	.7060	6.38	1.0310	9.31	1.3960	12.61
669.1	.4190	4.38	.9327	9.76	1.3790	14.43
652.4	.3935	4.22	.9285	9.96	1.4735	15.81
646.4	.3860	4.18	.9341	10.12	1.1860	12.84
1017.0	.2500	1.72	1.4894	10.25	3.4000	23.40
662.7	.4950	5.23	.9875	10.43	1.5850	16.74
627.2	.4705	5.25	.9749	10.88	1.5705	17.53
999.4	.2000	1.40	1.5688	10.99	2.8000	19.61
902.8	.6700	5.19	1.4519	11.26	2.5300	19.62
2453.4	.2500	.71	3.9831	11.36	7.1500	20.40
691.1	.7365	7.46	1.1396	11.54	1.7165	17.39
503.0	.4185	5.82	.8385	11.67	1.1185	15.57
819.1	.5625	4.81	1.3688	11.70	2.3725	20.28
814.4	.5500	4.73	1.3625	11.71	2.3600	20.28
1053.7	.1500	1.00	1.7688	11.75	3.4000	22.59
682.8	.5395	5.53	1.1983	12.28	2.1395	21.93
958.0	.3000	2.19	1.6938	12.38	2.2000	16.08
885.1	.2000	1.58	1.5969	12.63	3.2000	25.31
1199.0	.2000	1.17	2.1750	12.70	3.5000	20.43
687.9	.5085	5.17	1.2491	12.71	1.9785	20.13
960.8	.1500	1.09	1.7625	12.84	3.1000	22.59
518.6	.3720	5.02	.9551	12.89	1.3020	17.57
603.0	.5965	6.92	1.1290	13.11	1.8765	21.78
779.5	.1000	.90	1.4719	13.22	2.8000	25.14
681.0	.6865	7.06	1.3015	13.38	1.7565	18.06
676.7	.5400	5.59	1.2938	13.38	2.0200	20.90
557.3	.4880	6.13	1.1411	14.33	1.8880	23.71
568.3	.5820	7.17	1.1676	14.38	1.7920	22.07
846.4	.2500	2.07	1.9188	15.87	3.2000	26.47
927.2	.1500	1.13	2.6219	19.79	4.2000	31.71

**FRAGMENT WEIGHT-PRESENTED AREA DATA
FOR THE PROJECTILE INTERACTION AREA**

ARENA FIRING NO. 2

INTERACTION AREA 90 DEGREES AZIMUTHALLY

POLAR ZONE 95-100

NO. FRAGS SELECTED FOR MEASUREMENTS = 75

<u>Frag Wt (Grains)</u>	<u>Minimum Area</u>	<u>Gamma (in.²/lb)</u>	<u>Average Area</u>	<u>Gamma (in.²/lb)</u>	<u>Maximum Area</u>	<u>Gamma (in.²/lb)</u>
9407.7	1.5000	1.12	4.7813	3.56	8.1000	6.03
2160.2	.7000	2.27	1.3531	4.38	2.5000	8.10
3774.2	.8000	1.48	2.6188	4.86	4.0000	7.42
3565.9	.6500	1.28	2.7094	5.32	4.3000	8.44
2117.0	.3500	1.16	1.6844	5.57	2.5500	8.43
3265.0	.4000	.86	2.8125	6.03	6.9500	14.90
2104.7	.5000	1.66	1.9656	6.54	3.4000	11.31
1817.7	.1500	.58	1.7719	6.82	3.3000	12.71
4988.5	.9000	1.26	4.8906	6.86	10.3000	14.45
2171.0	.6000	1.93	2.1313	6.87	3.3000	10.64
1934.8	.4000	1.45	1.9469	7.04	4.0000	14.47
3203.3	.3500	.76	3.2750	7.16	7.4500	16.28
1541.4	.8000	3.63	1.6281	7.39	2.2500	10.22
1187.1	.7435	4.38	1.3041	7.69	2.0035	11.81
1520.3	.6270	2.89	1.6808	7.74	2.6470	12.19
1120.0	.6775	4.23	1.2675	7.92	1.6175	10.11
1479.5	.7965	3.77	1.7053	8.07	2.6465	12.52
1291.7	.8480	4.60	1.4924	8.09	2.3380	12.67
932.3	.4720	3.54	1.0914	8.19	1.6020	12.03
1573.6	.1900	.85	1.8469	8.22	3.0500	13.57
1296.9	.4000	2.16	1.5281	8.25	3.4000	18.35
1210.1	.6935	4.01	1.4323	8.29	2.1035	12.17
853.5	.5875	4.82	1.0238	8.40	1.4375	11.79
872.8	.5760	4.62	1.0610	8.51	1.5160	12.16
1190.9	.7210	4.24	1.4541	8.55	2.2810	13.41
1688.0	.4500	1.87	2.0938	8.68	4.8000	19.91
1010.7	.6710	4.65	1.2591	8.72	2.1110	14.62
1686.5	.3000	1.25	2.1031	8.73	4.8000	19.92
1664.9	.1500	.63	2.1000	8.83	3.3000	13.87
1941.1	.4000	1.44	2.4594	8.87	5.4000	19.47
1386.2	.2000	1.01	1.7688	8.93	3.1500	15.91
748.2	.5065	4.74	.9609	8.99	1.4865	13.91
1263.7	.7650	4.24	1.6338	9.05	2.3850	13.21
926.0	.4920	3.72	1.2314	9.31	1.8020	13.62
983.9	.3000	2.13	1.3125	9.34	2.5000	17.79
545.8	.3545	4.55	.7307	9.37	1.0145	13.01
958.1	.5080	3.71	1.2874	9.41	1.8580	13.57
978.7	.6280	4.49	1.3224	9.46	1.9380	13.86
1823.8	.4000	1.54	2.4813	9.52	5.4000	20.73
902.7	.2000	1.55	1.2394	9.61	2.2000	17.06
556.9	.4330	5.44	.7736	9.72	.9930	12.48
868.6	.2000	1.61	1.2094	9.75	2.3000	18.54
723.6	.6220	6.02	1.0201	9.87	1.3820	13.37
1345.6	.5500	2.86	1.9188	9.98	3.7500	19.51
829.5	.5765	4.86	1.1978	10.11	1.9365	16.34
649.5	.5475	5.90	.9525	10.27	1.3975	15.06
641.6	.4295	4.69	.9595	10.47	1.4195	15.49
559.7	.4935	6.17	.8385	10.49	1.1935	14.93

**FRAGMENT WEIGHT-PRESENTED AREA DATA
FOR THE PROJECTILE INTERACTION AREA**

ARENA FIRING NO. 2

INTERACTION AREA 90 DEGREES AZIMUTHALLY

POLAR ZONE 95-100

NO. FRAGS SELECTED FOR MEASUREMENTS - 75

<u>Frag Wt (Grains)</u>	<u>Minimum Area</u>	<u>Gamma (in.²/lb)</u>	<u>Average Area</u>	<u>Gamma (in.²/lb)</u>	<u>Maximum Area</u>	<u>Gamma (in.²/lb)</u>
873.5	.4900	3.93	1.3256	10.62	2.2900	18.35
667.2	.4580	4.81	1.0374	10.88	1.5780	16.56
694.3	.5550	5.60	1.0906	11.00	1.5550	15.68
835.5	.1000	.84	1.3188	11.05	2.1000	17.59
554.3	.3950	4.99	.8781	11.09	1.5750	19.89
973.0	.1000	.72	1.5469	11.13	3.4000	24.46
611.5	.5560	6.36	.9729	11.14	1.5560	17.81
652.6	.4050	4.34	1.0531	11.30	1.7150	18.40
801.1	.7065	6.17	1.3034	11.39	2.1465	18.76
1434.8	.2000	.98	2.4313	11.86	4.6000	22.44
848.9	.2000	1.65	1.4406	11.88	3.1500	25.97
657.4	.4835	5.15	1.1204	11.93	1.9335	20.59
598.4	.4180	4.89	1.0411	12.18	1.8180	21.27
1159.0	.2000	1.21	2.0531	12.40	3.7000	22.35
840.7	.7470	6.22	1.5126	12.59	2.5470	21.21
536.6	.4795	6.26	.9657	12.60	1.5995	20.87
544.7	.5120	6.58	.9807	12.60	1.1820	15.19
682.4	.5525	5.67	1.2400	12.72	2.1625	22.18
531.8	.5135	6.76	.9704	12.77	1.7335	22.82
892.0	.1000	.78	1.6313	12.80	2.5000	19.62
566.2	.5915	7.31	1.0459	12.93	1.3715	16.96
552.0	.4320	5.48	1.0214	12.95	1.5620	19.81
807.0	.7840	6.80	1.5209	13.19	2.4840	21.55
539.1	.4765	6.19	1.0646	13.82	1.7365	22.55
589.7	.5525	6.56	1.2788	15.18	2.2725	26.98
708.3	.1500	1.48	1.5688	15.50	2.3000	22.73
536.7	.6495	8.47	1.1933	15.56	1.7695	23.08

FRAGMENT HAZARD INVESTIGATION

Test Number: QD-155-08

Item Tested: M107 155mm projectile containing 15 lb of TNT explosive and equipped with a modified M564 nose fuze.

Number of Firings and Dates: 1 - 26 August 1976
1 - 23 September 1976

Number of Items per Firing: 8

Location of Test: NSWC/DL - Experimental Explosive Area

Arena Configuration: Polar Arena

Fragment Recovery - 0°-180° Polar by 11° azimuthal

Fragment Velocities - 0°-180° Polar by 27° azimuthal

Projectile Orientation: Two horizontal rows of four projectiles in a pallet with all centerlines seven inches apart.

Meteorology:

26 August 1976	Barometric Pressure	- 28.65 in. Hg
	Temperature	- 93°F
23 September 1976	Barometric Pressure	- 29.90 in. Hg
	Temperature	- 85°F

Instrumentation: Fragment Velocity - Five high speed motion picture cameras; black and white film.

Documentation - Two high speed motion picture cameras; color film.

Post Test Comments: Well defined fragment concentrations formed in the Celotex and witness panels for both firings.

A collection of large ground fragments was conducted.

**FRAGMENT VELOCITIES AVERAGED
FOR THE TWO FIRINGS OF
TEST NO. QD-155-08**

Polar Zone (deg)	Avg Frag Velocity* (ft/s)
0- 5	5422.61
5- 10	5167.69
10- 15	5360.22
15- 20	4662.33
20- 25	3850.92
25- 30	4587.16
30- 35	0.00
35- 40	4180.89
40- 45	5352.83
45- 50	6147.51
50- 55	6513.62
55- 60	7932.09
60- 65	8399.03
65- 70	8943.74
70- 75	9075.24
75- 80	9100.18
80- 85	7764.21
85- 90	7643.98
90- 95	8141.18
95-100	8425.30
100-105	8823.95
105-110	8966.20
110-115	9045.10
115-120	8842.99
120-125	5220.55
125-130	3995.83
130-135	4297.35
135-140	5882.35
140-145	5284.78
145-150	4241.84
150-155	5718.95
155-160	6507.10
160-165	6947.32
165-170	6354.11
170-175	6328.77
175-180	6339.65

*Velocities recorded at 25.0 ft stand-off

**FRAGMENT WEIGHT AND NUMBER TOTALS COMBINED FOR
POLAR ZONES 0°-180° OF TEST NO. QD-155-08
(FIRST FIRING)**

<u>Weight Group (Grains)</u>	<u>No. of Frgs</u>	<u>Total Weight</u>
.1- 100.0	5243.0	66283.0
100.0- 300.0	499.0	88091.4
300.0- 500.0	158.0	61786.4
500.0- 600.0	41.0	22233.9
600.0- 700.0	36.0	23574.0
700.0- 800.0	39.0	28799.6
800.0- 900.0	30.0	25555.9
900.0-1000.0	27.0	25832.1
1000.0-1200.0	41.0	45143.9
1200.0-1400.0	34.0	43795.1
1400.0-1700.0	31.0	48050.6
1700.0-2000.0	23.0	42676.3
2000.0-2500.0	20.0	43537.4
2500.0-3000.0	10.0	27841.9
3000.0 +	13.0	51875.7

**FRAGMENT WEIGHT-PRESENTED AREA DATA
FOR TEST NO. QD-155-08
(FIRST FIRSING)**

Polar Zones 0°-180°

No. of Frags Selected for Measurements = 242

Frag Wt (Grains)	Minimum Area	Presented Area (in. ²)		Average Area	Gamma (in. ² /lb)	Maximum Area	Gamma (in. ² /lb)
		Gamma (in. ² /lb)					
4027.2	.8500	1.48	2.5094	4.36	4.0000	6.95	
7607.0	.4000	.37	5.0750	4.67	9.7000	8.93	
2970.3	.6000	1.41	2.0969	4.94	3.3500	7.89	
3488.7	.6000	1.20	2.4750	4.97	4.0000	8.03	
3356.0	.3500	.73	2.4531	5.12	4.0500	8.45	
3326.7	.3500	1.16	2.4438	5.14	4.6000	9.68	
4215.5	1.8500	3.07	3.1156	5.17	4.3000	7.14	
3229.5	.3100	.67	2.4000	5.20	3.9900	8.65	
1370.0	.0501	.26	1.0454	5.34	3.7200	19.01	
2834.5	.5000	1.23	2.2375	5.53	3.6000	8.89	
3136.9	.6000	1.34	2.5844	5.77	3.8500	8.59	
2296.0	.3000	.91	2.0500	6.25	4.0000	12.20	
1361.3	.5000	2.57	1.2750	6.56	1.6500	8.48	
750.1	.0500	.47	.7062	6.59	1.1500	10.73	
1919.5	.3000	1.09	1.8375	6.70	3.1000	11.31	
2010.5	1.3500	4.70	1.9313	6.72	2.9000	10.10	
986.4	.4000	2.84	.9531	6.76	1.6000	11.35	
2181.8	.5500	1.76	2.1375	6.86	3.0000	9.63	
1133.2	.9000	5.56	1.1188	6.91	1.4000	8.65	
1300.1	.4000	2.15	1.2938	6.97	2.1500	11.58	
1053.5	.6900	4.58	1.0613	7.05	1.8000	11.96	
2146.4	.9000	2.94	2.1625	7.05	3.4000	11.09	
2328.4	.4000	1.20	2.3781	7.15	4.1500	12.48	
1749.8	.3000	1.20	1.7888	7.16	3.3900	13.56	
1394.5	.1000	.50	1.4325	7.19	2.7000	13.55	
1817.7	.4000	1.54	1.9031	7.33	3.2500	12.52	
1417.2	.5000	2.47	1.4888	7.35	2.1000	10.37	
2032.1	.5000	1.72	2.1719	7.48	3.7500	12.92	
2049.1	.3000	1.02	2.2063	7.54	3.3000	11.27	
1222.6	.5000	2.86	1.3263	7.59	1.8400	10.53	
2936.3	.2000	.48	3.1863	7.60	5.5000	13.11	
1225.2	.6500	3.71	1.3338	7.62	2.0500	11.71	
2115.5	.5500	1.82	2.3063	7.63	3.7500	12.41	
995.8	.4000	2.81	1.0875	7.64	2.2000	15.46	
789.1	.4500	3.99	.8625	7.65	1.4000	12.42	
2016.7	.3000	1.04	2.2238	7.72	4.0000	13.88	
1088.2	.7000	4.50	1.2000	7.72	1.5000	9.65	
2095.4	1.0500	3.51	2.3144	7.73	3.4000	11.36	
1548.3	.6000	2.71	1.7113	7.74	2.5000	11.30	
2819.1	.3000	.74	3.1200	7.75	5.3000	13.16	
3390.0	.6500	1.34	3.7594	7.76	7.1000	14.66	
1063.1	.5000	3.29	1.1813	7.78	1.8000	11.85	
3315.9	.3900	.82	3.6994	7.81	7.3000	15.41	
2691.0	.3000	.78	3.0125	7.84	5.3000	13.79	
986.3	.1500	1.06	1.1125	7.90	1.7000	12.07	
1856.2	.5500	2.07	2.0975	7.91	3.7700	14.22	
1083.4	.3000	1.94	1.2250	7.91	1.7000	10.98	
1324.0	.1500	.79	1.5031	7.95	2.4000	12.69	
1224.5	.3000	1.71	1.3925	7.96	2.0500	11.72	

**FRAGMENT WEIGHT-PRESENTED AREA DATA
FOR TEST NO. QD-155-08
(FIRST FIRING)**

Polar Zones 0°-180°

No. of Frags Selected for Measurements = 242

Frag Wt (Grains)	Minimum Area	Presented Area (in. ²)		Average Area	Gamma (in. ² /lb)	Maximum Area	Gamma (in. ² /lb)
		Gamma (in. ² /lb)	Gamma (in. ² /lb)				
856.0	.3000	2.45	.9750	7.97	1.5000	12.27	
1206.8	.8900	5.16	1.3775	7.99	1.7500	10.15	
1330.6	.2000	1.05	1.5281	8.04	2.6500	13.94	
1056.5	.5000	3.31	1.2250	8.12	1.8000	11.93	
1287.0	.7000	3.81	1.4969	8.14	2.0500	11.15	
612.1	.1000	1.14	.7125	8.15	1.1000	12.58	
1047.7	.1500	1.00	1.2250	8.18	2.3000	15.37	
1870.1	1.0000	3.74	2.1956	8.22	3.5500	13.29	
955.3	.4000	2.93	1.1219	8.22	1.9500	14.29	
1018.3	.1500	1.03	1.2031	8.27	2.3000	15.81	
1641.8	.4500	1.92	1.9438	8.29	3.8000	16.20	
641.4	.5500	6.00	.7594	8.29	.9000	9.82	
1905.6	.3100	1.14	2.2613	8.31	4.3000	15.80	
991.3	.0900	.64	1.1781	8.32	2.1000	14.83	
855.3	.3000	2.46	1.0188	8.34	1.5000	12.28	
1128.4	.3000	1.86	1.3688	8.49	2.1000	13.03	
751.3	.2000	1.86	.9125	8.50	1.9000	17.70	
804.6	.7000	6.09	.9812	8.54	1.4000	12.18	
988.7	.1500	1.06	1.2063	8.54	1.8500	13.10	
909.7	.6000	4.62	1.1188	8.61	1.5000	11.54	
1229.1	.1100	.63	1.5275	8.70	2.3100	13.16	
1706.6	.3100	1.27	2.1213	8.70	3.6500	14.97	
1348.7	.3000	1.56	1.6875	8.76	3.1000	16.09	
1107.7	.8000	5.06	1.3906	8.79	1.9500	12.32	
506.9	.1000	1.38	.6406	8.85	1.0000	13.81	
1133.6	.4500	2.78	1.4375	8.88	2.2000	13.59	
1412.5	.2900	1.44	1.7950	8.90	3.2500	16.11	
642.0	.6500	7.09	.8187	8.93	1.1000	11.99	
1037.2	.1500	1.01	1.3250	8.94	2.1000	14.17	
1120.3	.2500	1.56	1.4344	8.96	2.4000	15.00	
1164.7	.2900	1.74	1.4931	8.97	2.4000	14.42	
2967.2	.3000	.71	3.8175	9.01	6.4000	15.10	
1725.1	.5000	2.03	2.2219	9.02	4.2100	17.08	
878.3	.3000	2.39	1.1375	9.07	1.9000	15.14	
1299.9	.8000	4.31	1.6844	9.07	2.7500	14.81	
823.6	.4000	3.40	1.0688	9.08	1.5000	12.75	
1158.4	.3500	2.11	1.5113	9.13	2.3000	13.90	
3010.4	3.9100	9.09	3.9300	9.14	3.9500	9.18	
622.0	.1500	1.69	.8125	9.14	1.2500	14.07	
512.9	.1000	1.36	.6719	9.17	1.3000	17.74	
756.4	.3200	2.96	.9925	9.18	1.8000	16.66	
711.2	.1000	.98	.9362	9.22	1.5000	14.76	
659.7	.4000	4.24	.8687	9.22	1.3000	13.79	
704.6	.1500	1.49	.9281	9.22	1.6000	15.90	
1902.5	.2000	.74	2.5063	9.22	4.0000	14.72	
1199.2	.3500	2.04	1.5813	9.23	2.3500	13.72	
880.6	.2900	2.31	1.1613	9.23	1.9000	15.10	
669.6	.2500	2.61	.8844	9.25	1.5000	15.68	
1703.5	.2500	1.03	2.2500	9.25	3.7500	15.41	

FRAGMENT WEIGHT-PRESENTED AREA DATA
FOR TEST NO. QD-155-08
(FIRST FIRING)

Polar Zones 0°-100°

No. of Frags Selected for Measurements = 242

<u>Frag Wt</u> <u>(Grains)</u>	<u>Minimum</u> <u>Area</u>	<u>Presented Area (in.²)</u> <u>Gamma</u> <u>(in.²/lb)</u>	<u>Average</u> <u>Area</u>	<u>Gamma</u> <u>(in.²/lb)</u>	<u>Maximum</u> <u>Area</u>	<u>Gamma</u> <u>(in.²/lb)</u>
1063.6	.4000	2.63	1.4063	9.26	2.1000	13.82
1322.9	.2000	1.06	1.7513	9.27	3.0000	15.87
953.7	.2500	1.83	1.2656	9.29	2.2000	16.15
889.7	.3000	2.36	1.1813	9.29	2.1000	16.52
757.2	.3000	2.77	1.0063	9.30	1.5500	14.33
840.4	.0500	.42	1.1213	9.34	1.8000	14.99
650.4	.3000	3.23	.8687	9.35	1.4000	15.07
1617.1	.3000	1.30	2.1625	9.36	3.5000	15.15
641.7	.3000	3.27	.8625	9.41	1.3000	14.18
863.9	.9000	7.29	1.1625	9.42	1.5000	12.15
545.5	.1500	1.92	.7375	9.46	1.2000	15.40
705.9	.3000	2.97	.9562	9.48	1.6000	15.87
709.8	.1500	1.48	.9625	9.49	1.5500	15.29
1184.0	.4500	2.66	1.6063	9.50	2.7500	16.26
692.8	.1400	1.41	.9425	9.52	1.5000	15.16
689.1	.3000	3.05	.9375	9.52	1.6000	16.25
587.9	.2500	2.98	.8000	9.53	1.2500	14.88
683.6	.2000	2.05	.9312	9.54	1.4000	14.34
1200.7	.3000	1.75	1.6363	9.54	2.6000	15.16
1013.9	.4000	2.76	1.3844	9.56	2.5500	17.51
1735.9	.6500	2.62	2.3750	9.58	4.0000	16.13
1096.1	.2000	1.28	1.5000	9.58	2.4000	15.33
556.6	.1500	1.89	.7625	9.59	1.2000	15.09
877.0	.4000	3.19	1.2031	9.60	2.0500	16.36
846.7	.4000	3.31	1.1625	9.61	2.0000	16.53
633.9	.4500	4.97	.8750	9.66	1.6000	17.67
1468.4	.2400	1.14	2.0306	9.68	4.4000	20.98
506.1	.1000	1.38	.7000	9.68	1.2000	16.60
2581.4	.4000	1.08	3.5763	9.70	7.4000	20.07
830.2	.8000	6.75	1.1531	9.72	1.7500	14.76
863.3	.3000	2.43	1.2000	9.73	2.2000	17.84
1995.1	.3500	1.23	2.7738	9.73	5.0500	17.72
780.9	.2500	2.24	1.0888	9.76	1.8500	16.58
1013.7	.1000	.69	1.4138	9.76	2.0000	13.81
1087.6	.3000	1.93	1.5188	9.77	3.0000	19.31
1330.9	.2000	1.05	1.8613	9.79	3.1000	16.30
897.1	.3000	2.34	1.2625	9.85	2.3000	17.95
801.8	.2500	2.18	1.1313	9.88	1.7000	14.84
535.1	.1500	1.96	.7562	9.89	1.5500	20.28
694.1	.1000	1.01	.9812	9.90	1.7000	17.14
879.2	.3000	2.39	1.2438	9.90	2.2000	17.52
1279.8	.1000	.55	1.0219	9.96	3.0000	16.41
528.9	.2000	2.65	.7562	10.01	1.3000	17.21
646.2	.2500	2.71	.9281	10.05	1.7000	18.42
739.7	.5000	4.73	1.0625	10.05	1.8000	17.03
723.7	.1000	.97	1.0406	10.07	1.6500	15.96
2033.7	.4000	1.38	2.9250	10.07	4.9000	16.87
768.7	.2000	1.82	1.1063	10.07	1.8000	16.39
1184.3	.3500	2.07	1.7050	10.08	2.7000	15.96

**FRAGMENT WEIGHT-PRESENTED AREA DATA
FOR TEST NO. QD-155-08
(FIRST FIRING)**

Polar Zones 0°-180°

No. of Frag Selected for Measurements = 242

Frag Wt (Grains)	Presented Area (in. ²)		Average Area	Gamma (in. ² /lb)	Maximum Area	Gamma (in. ² /lb)
	Minimum Area	Gamma (in. ² /lb)				
716.7	.1000	.98	1.0344	10.10	1.6500	16.12
1097.3	.5000	3.19	1.5875	10.13	2.3000	14.67
1248.5	.2500	1.40	1.8188	10.20	3.0000	16.82
728.2	.2000	1.92	1.0688	10.27	1.8000	17.30
523.3	.1000	1.34	.7687	10.27	1.2500	16.72
1522.8	.4000	1.84	2.2413	10.30	3.7500	17.24
707.7	.1500	1.48	1.0438	10.32	1.8500	18.30
2296.0	.3000	.91	3.3875	10.33	6.2000	18.90
710.4	.1900	1.87	1.0550	10.40	1.6500	16.26
524.6	.1000	1.33	.7812	10.42	1.3500	18.01
1065.4	.3000	1.97	1.5875	10.43	2.5000	16.43
1160.9	.2500	1.51	1.7406	10.50	3.5000	21.10
918.8	.2000	1.52	1.3875	10.57	2.4000	18.28
957.2	.1900	1.39	1.4488	10.59	2.1000	15.36
667.9	.1500	1.57	1.0156	10.64	1.8000	18.87
976.0	.3500	2.51	1.4875	10.67	2.3000	16.50
706.7	.3000	2.97	1.0794	10.69	1.9900	19.71
519.0	.1500	2.02	.7981	10.76	1.5000	20.23
974.8	.2500	1.80	1.5000	10.77	2.4000	17.23
920.1	.5000	3.80	1.4250	10.84	2.4000	18.26
851.0	.2000	1.65	1.3188	10.85	2.1000	17.27
1305.4	.2000	1.07	2.0238	10.85	3.9000	20.91
1232.7	.3000	1.70	1.9125	10.86	3.5000	19.88
1476.7	.1500	.71	2.2950	10.88	4.7000	22.28
621.0	.0500	.56	.9656	10.88	1.4000	15.78
830.4	.2000	1.69	1.2969	10.93	2.2500	18.97
561.4	.2000	2.49	.8812	10.99	1.3500	16.83
1834.6	.2000	.76	2.8938	11.04	6.0000	23.66
786.7	.4500	4.00	1.2438	11.07	2.1500	19.13
775.8	.1500	1.35	1.2281	11.08	1.7000	15.34
963.0	.2500	1.82	1.5281	11.11	2.2000	15.99
1557.6	.1500	.67	2.4750	11.12	3.7500	16.85
1913.3	.2000	.73	3.0438	11.14	5.1000	18.66
987.2	.6500	4.61	1.5750	11.17	2.9000	20.56
583.0	.3000	3.60	.9312	11.18	1.3000	15.61
730.3	.1000	.96	1.1706	11.22	1.8400	17.64
594.5	.2000	2.35	.9562	11.26	1.6500	19.43
843.0	.3000	2.49	1.3563	11.26	2.2000	18.27
2160.2	.3000	.97	3.4888	11.31	6.8000	22.03
714.6	.2000	1.96	1.1563	11.33	1.9000	18.61
689.8	.200	.20	1.1163	11.33	1.8100	18.37
1128.9	.5000	3.10	1.8313	11.36	3.0000	18.60
2444.1	2.9000	8.31	3.9844	11.41	4.5000	12.89
1195.4	.2000	1.17	1.9500	11.42	3.1000	18.15
740.5	.1000	.95	1.2188	11.52	1.7500	16.54
1499.8	.2000	.93	2.4688	11.52	4.4900	20.96
1515.6	.2000	.92	2.5000	11.55	4.5000	20.78
1000.3	.2000	1.40	1.6563	11.59	3.0500	21.34
563.5	.3000	3.73	.9362	11.63	1.4400	17.89

FRAGMENT WEIGHT-PRESENTED AREA DATA
FOR TEST NO. QD-155-08
(FIRST FIRING)

Polar Zones 0°-180°

No. of Frags Selected for Measurements = 242

<u>Frag Wt</u> <u>(Grains)</u>	<u>Minimum</u> <u>Area</u>	<u>Presented Area (in.²)</u> <u>Gamma</u> <u>(in.²/lb)</u>	<u>Average</u> <u>Area</u>	<u>Gamma</u> <u>(in.²/lb)</u>	<u>Maximum</u> <u>Area</u>	<u>Gamma</u> <u>(in.²/lb)</u>
1678.8	.4900	2.04	2.7894	11.63	5.4500	22.72
1161.8	.2000	1.21	1.9406	11.69	3.7500	22.59
597.9	.2000	2.34	1.0000	11.71	1.5000	18.15
875.8	.2000	1.60	1.4688	11.74	2.7500	21.98
1045.7	.4000	2.68	1.7594	11.78	3.7500	25.10
529.1	.1500	1.98	.8937	11.82	1.3500	17.86
863.9	.5000	4.05	1.4656	11.88	2.2500	18.23
1612.4	.1500	.65	2.7531	11.95	5.2000	22.58
720.9	.2500	2.43	1.2331	11.97	1.9500	18.93
828.2	.2000	1.69	1.4219	12.02	2.6500	22.40
648.8	.1500	1.62	1.1200	12.08	1.9500	21.04
727.2	.2000	1.93	1.2563	12.09	2.0000	19.25
525.1	.1500	2.00	.9125	12.16	1.6000	21.33
843.2	.0500	.42	1.4688	12.19	2.6000	21.58
527.5	.5000	6.64	.9250	12.27	1.2500	16.59
523.7	.1000	1.34	.9187	12.28	1.7000	22.72
915.5	.3500	2.68	1.6063	12.28	2.7500	21.03
1435.3	.2500	1.22	2.5363	12.37	4.9500	24.14
644.1	.0500	.54	1.1406	12.40	2.2000	23.91
1150.7	.3000	1.82	2.0438	12.43	3.1000	18.86
719.2	.1200	1.17	1.2775	12.43	2.6000	25.31
646.6	.0500	.54	1.1531	12.48	2.3500	25.44
982.5	.5000	3.56	1.7563	12.51	2.8000	19.95
1113.5	.1500	.94	1.9906	12.51	3.3500	21.06
713.3	.1000	.98	1.2813	12.57	2.5000	24.53
654.5	.2500	2.67	1.1813	12.63	2.0500	21.93
707.9	.0500	.49	1.2844	12.70	2.5000	24.72
566.3	.1500	1.85	1.0331	12.77	2.1200	26.21
529.6	.1000	1.32	.9687	12.80	2.1000	27.76
1391.4	.2000	1.01	2.5594	12.88	4.8000	24.15
662.1	.1000	1.06	1.2438	13.15	2.0000	21.14
972.3	.1500	1.08	1.8406	13.25	3.4500	24.84
547.0	.3000	3.84	1.0438	13.36	1.7000	21.76
749.3	.2500	2.34	1.4488	13.53	2.5500	23.82
570.2	.1500	1.84	1.1038	13.55	1.7900	21.97
948.8	.2000	1.48	1.8375	13.56	3.3500	24.72
551.1	.2000	2.54	1.0719	13.61	2.0500	26.04
552.4	.0100	.13	1.0763	13.64	1.6000	20.28
507.7	.7000	9.65	1.0063	13.87	1.4500	19.99
513.3	.1500	2.05	1.0231	13.95	1.7000	23.18
749.0	.2000	1.87	1.5188	14.19	2.9500	27.57
544.5	.2000	2.57	1.1438	14.70	1.9000	24.43
718.3	.2000	1.95	1.5188	14.80	3.0000	29.24
774.8	.1000	.90	1.6563	14.96	3.0000	27.10
602.6	.0500	.58	1.3313	15.46	2.2000	25.56
631.2	.1000	1.11	1.4488	16.07	2.7000	29.94

**FRAGMENT WEIGHT AND NUMBER TOTALS COMBINED FOR
POLAR ZONES 0°-180° OF TEST NO. QD-155-08
(2nd FIRING)**

<u>Weight Group (Grains)</u>	<u>No. of Fragments</u>	<u>Total Weight</u>
.1- 100.0	4674.0	56479.2
100.0- 300.0	454.0	81544.9
300.0- 500.0	157.0	61177.1
500.0- 600.0	47.0	25925.2
600.0- 700.0	40.0	26011.8
700.0- 800.0	25.0	18722.7
800.0- 900.0	26.0	22329.1
900.0-1000.0	22.0	20742.9
1000.0-1200.0	36.0	39232.8
1200.0-1400.0	32.0	41291.1
1400.0-1700.0	23.0	35467.8
1700.0-2000.0	19.0	35705.0
2000.0-2500.0	12.0	27019.3
2500.0-3000.0	8.0	21953.7
3000.0 +	15.0	145529.5

FRAGMENT WEIGHT-PRESENTED AREA DATA
FOR TEST NO. QD-155-08
(2nd FIRING)

Polar Zones 0°-180°

No. of Frags Selected for Measurements = 231

Frag Wt (Grains)	Presented Area (in. ²)		Average Area	Gamma (in. ² /lb)	Maximum Area	Gamma (in. ² /lb)
	Minimum Area	Gamma (in. ² /lb)				
10780.9	2.0000	1.30	4.6063	2.99	7.6000	4.93
5843.3	1.5000	1.80	4.6438	5.56	7.2000	8.63
1902.5	.4000	1.47	1.5200	5.59	2.6500	9.75
1661.8	.4500	1.90	1.3831	5.83	2.1500	9.06
3991.7	1.0500	1.84	3.3563	5.89	6.0500	10.61
1220.6	.4000	2.29	1.0688	6.13	1.6000	9.18
2735.7	.3000	.77	2.4175	6.19	4.1000	10.49
1688.1	.9100	3.77	1.4981	6.21	2.1000	8.71
1862.4	.2100	.79	1.6675	6.27	3.1000	11.65
1593.3	.1100	.48	1.4331	6.30	2.4000	10.54
1879.4	.7000	2.61	1.6938	6.31	2.6000	9.68
2194.1	1.2000	3.83	1.9944	6.36	2.7000	8.61
2279.0	.5000	1.54	2.0750	6.37	3.5000	10.75
2697.2	1.1000	2.85	2.4594	6.38	3.4500	8.95
2630.8	.8000	2.13	2.4525	6.53	3.7300	9.92
1182.3	.5000	2.96	1.1125	6.59	1.6000	9.47
3891.4	.4000	.72	3.7000	6.66	8.1000	14.57
1299.3	.3000	1.62	1.2500	6.73	2.0000	10.78
1547.4	.6000	2.71	1.4938	6.76	2.5000	11.31
748.8	.1500	1.40	.7325	6.85	1.1000	10.28
1307.1	.3000	1.61	1.2800	6.85	1.9000	10.18
2370.0	1.1000	3.25	2.3563	6.96	3.2000	9.45
1566.1	.9000	4.02	1.5625	6.98	2.4000	10.73
4340.5	.2900	.47	4.3363	6.99	7.9500	12.82
1286.2	.3000	1.63	1.3375	7.28	2.0000	10.88
731.1	.2800	2.68	.7612	7.29	1.0000	9.57
1290.5	.3700	2.01	1.3481	7.31	1.9000	10.31
1413.9	.6000	2.97	1.4900	7.38	2.4000	11.88
2624.6	.9000	2.40	2.7688	7.38	4.2000	11.20
3093.7	1.4000	3.17	3.2875	7.44	4.6000	10.41
1123.9	.3100	1.93	1.1988	7.47	1.9300	12.02
1281.7	.9100	4.97	1.3700	7.48	1.9000	10.38
2192.6	.1400	.45	2.3450	7.49	4.2000	13.41
1541.4	.7500	3.41	1.6500	7.49	2.2000	9.99
1273.6	.8000	4.40	1.3656	7.51	1.7500	9.62
1474.3	.4000	1.90	1.5875	7.54	2.5000	11.87
662.6	.2100	2.22	.7138	7.54	1.2000	12.68
1344.0	.1000	.52	1.4500	7.55	2.5000	13.02
1109.8	.4500	2.84	1.2000	7.57	1.8000	11.35
1987.4	.3000	1.06	2.1656	7.63	3.7000	13.03
951.5	.5500	4.05	1.0375	7.63	1.3000	9.56
1100.0	.5500	3.50	1.2000	7.64	1.7500	11.14
2900.8	.9000	2.17	3.1688	7.65	5.2000	12.55
1589.6	.9000	3.96	1.7563	7.73	2.4000	10.57
786.3	.3500	3.12	.8812	7.85	1.3000	11.57
591.9	.1000	1.18	.6750	7.98	1.1000	13.01
780.5	.3000	2.69	.8937	8.02	1.4000	12.56
757.0	.3000	2.77	.8675	8.02	1.4500	13.41

**FRAGMENT WEIGHT-PRESENTED AREA DATA
FOR TEST NO. QD-155-08
(2nd FIRING)**

Polar Zones 0°-180°

No. of Frags Selected for Measurements = 231

<u>Frag Wt (Grains)</u>	<u>Minimum Area</u>	<u>Presented Area (in.²) Gamma (in.²/lb)</u>	<u>Average Area</u>	<u>Gamma (in.²/lb)</u>	<u>Maximum Area</u>	<u>Gamma (in.²/lb)</u>
906.2	.3000	2.32	1.0406	8.04	1.6500	12.75
1621.7	.7000	3.02	1.8813	8.12	3.2000	13.81
1092.3	.4500	2.88	1.2781	8.19	1.8500	11.85
1435.6	.4000	1.95	1.7000	8.29	2.8000	13.65
1076.1	.2000	1.30	1.2750	8.29	2.1000	13.66
1100.5	.1200	.76	1.3069	8.31	2.2500	14.31
1931.8	.8500	3.08	2.3000	8.33	3.7500	13.59
1820.7	1.1000	4.23	2.1688	8.34	3.4000	13.07
1262.0	1.0500	5.82	1.5063	8.35	1.9000	10.54
1517.5	.3000	1.38	1.8125	8.36	2.8000	12.92
1248.1	.1500	.84	1.4938	8.38	2.4000	13.46
1060.2	.2500	1.65	1.2719	8.40	2.1000	13.87
838.2	.6000	5.01	1.0063	8.40	1.6000	13.36
775.3	.0500	.45	.9375	8.46	1.6000	14.45
1490.6	.4500	2.11	1.8050	8.48	3.8000	17.85
1042.3	.1500	1.01	1.2656	8.50	2.2000	14.78
880.4	.4100	3.26	1.0725	8.53	1.5500	12.32
1088.7	.3500	2.25	1.3281	8.54	2.3000	14.79
1922.6	1.1000	4.00	2.3500	8.56	3.4000	12.38
2390.1	.3000	.88	2.9363	8.60	5.7000	16.69
1922.6	.3900	1.42	2.3675	8.62	4.3000	15.66
1212.4	.7000	4.04	1.4938	8.62	2.4000	13.86
695.1	.1200	1.21	.8587	8.65	1.4500	14.60
844.0	.2100	1.74	1.0456	8.67	1.7000	14.10
1056.2	.1500	.99	1.3094	8.68	2.2000	14.58
3297.4	.4500	.96	4.1081	8.72	8.0500	17.09
2459.5	.2000	.57	3.0988	8.82	5.4000	15.37
620.2	.2500	2.82	.7875	8.89	1.2000	13.54
1283.4	.8000	4.36	1.6313	8.90	2.3000	12.54
1499.0	.1100	.51	1.9075	8.91	3.4000	15.88
948.6	.3000	2.21	1.2088	8.92	2.0000	14.76
573.0	.1000	1.22	.7312	8.93	1.1500	14.05
1888.6	1.0500	3.89	2.4138	8.95	3.7500	13.90
683.5	.1300	1.33	.8737	8.95	1.2000	12.29
702.3	.2100	2.09	.9031	9.00	1.5000	14.95
886.0	.2500	1.98	1.1438	9.04	1.8000	14.22
1324.6	.3000	1.59	1.7138	9.06	2.6000	13.74
984.7	.8000	5.69	1.2769	9.08	1.8000	12.80
3332.9	.9000	1.89	4.3300	9.09	7.1000	14.91
788.6	.4000	3.55	1.0313	9.15	1.6000	14.20
976.2	.2000	1.43	1.2788	9.17	2.2000	15.78
672.6	.5000	5.20	.8844	9.20	1.2000	12.49
1176.0	.7500	4.46	1.5500	9.23	2.3000	13.69
948.3	.2000	1.48	1.2500	9.23	2.0000	14.76
1175.2	.2500	1.49	1.5525	9.25	2.7000	16.08
1298.8	.9500	5.12	1.7188	9.26	2.4500	13.20
763.4	.1000	.92	1.0125	9.28	1.6000	14.67
910.6	.1500	1.15	1.2094	9.30	2.2000	16.91
1022.5	.2500	1.71	1.3588	9.30	2.1800	14.92

**FRAGMENT WEIGHT-PRESENTED AREA DATA
FOR TEST NO. QD-155-08
(2nd FIRING)**

Polar Zones 0°-180°

No. of Frags Selected for Measurements = 231

Presented Area (in. ²)						
Frag Wt (Grains)	Minimum Area	Gamma (in. ² /lb)	Average Area	Gamma (in. ² /lb)	Maximum Area	Gamma (in. ² /lb)
966.7	.2000	1.45	1.2863	9.31	1.9000	13.76
884.2	.5500	4.35	1.1813	9.35	1.6000	12.67
2052.2	.1500	.51	2.7431	9.36	5.5000	18.76
1249.8	.7000	3.92	1.6719	9.36	2.7000	15.12
764.7	.3000	2.75	1.0250	9.38	1.5000	13.73
676.0	.3000	3.11	.9062	9.38	1.3000	13.46
1038.9	.1500	1.01	1.3938	9.39	2.2500	15.16
1729.7	.8000	3.24	2.3325	9.44	3.9500	15.99
624.4	.2100	2.35	.8444	9.47	1.4000	15.70
563.7	.1500	1.86	.7625	9.47	1.2000	14.90
2461.1	.6000	1.71	3.3363	9.49	5.7500	16.35
926.2	.2500	1.89	1.2563	9.49	2.1900	16.55
929.8	.3000	2.26	1.2688	9.55	1.9000	14.30
663.9	.1500	1.58	.9094	9.59	1.3000	13.71
1271.8	.5000	.28	1.7488	9.63	3.2000	17.61
684.9	.0500	.51	.9437	9.65	1.4000	14.31
1307.0	.9000	4.82	1.8113	9.70	2.8000	15.00
1632.5	.3000	1.29	2.2625	9.70	4.6000	19.72
552.1	.6500	8.24	.7656	9.71	.9000	11.41
711.9	.2000	1.97	.9875	9.71	1.7000	16.72
1130.2	.3500	2.17	1.5688	9.72	3.2000	19.82
1038.2	.3000	2.02	1.4463	9.75	2.2000	14.83
618.9	.0500	.57	.8625	9.76	1.4000	15.83
1238.8	.1000	.57	1.7375	9.82	3.2000	18.08
897.6	.3500	2.73	1.2625	9.85	2.1500	16.77
630.2	.2000	2.22	.8927	9.93	1.5000	16.66
901.6	.3500	2772	1.2513	9.95	2.1000	16.30
1525.0	.4000	1.84	2.1688	9.95	3.3000	15.15
618.3	.2000	2.26	.8812	9.98	1.4500	16.42
594.7	.1000	1.18	.8487	9.99	1.5000	18.24
585.4	.5000	5.98	.8375	10.01	1.2000	14.35
835.9	.0500	.42	1.1963	10.02	2.2000	18.42
1329.0	.2500	1.32	1.9113	10.07	3.5000	18.43
1423.3	.4000	1.97	2.0513	10.09	3.8000	18.69
1327.1	.2500	1.32	1.9156	10.10	3.3000	17.41
822.1	.2500	2.13	1.1938	10.16	1.8500	15.75
530.9	.1100	1.45	.7731	10.19	1.2500	16.48
624.3	.4500	5.05	.9125	10.23	1.2500	14.02
2961.0	.4500	1.06	4.3500	10.28	7.2500	17.14
587.0	.3000	3.58	.8637	10.30	1.2100	14.43
954.6	.3000	2.20	1.4063	10.31	2.1000	15.40
868.5	.2000	1.61	1.2875	10.38	2.2000	17.73
626.2	.2000	2.24	.9437	10.55	1.5000	16.77
820.2	.4000	3.41	1.2388	10.57	2.1000	17.92
730.4	.2500	2.40	1.1063	10.60	1.6000	15.33
1469.8	.1100	.52	2.2513	10.72	4.0000	19.05
1255.0	.7500	4.18	1.9250	10.74	3.5000	19.52
658.4	.3500	3.72	1.0125	10.76	1.6000	17.01
518.2	.3500	4.73	.7975	10.77	1.3000	17.56

**FRAGMENT WEIGHT-PRESENTED AREA DATA
FOR TEST NO. QD-155-08
(2nd FIRING)**

Polar Zones 0°-180°

No. of Frags Selected for Measurements = 231

Frag Wt (Grains)	Minimum Area	Presented Area (in. ²)		Average Area	Gamma (in. ² /lb)	Maximum Area	Gamma (in. ² /lb)
		Gamma (in. ² /lb)					
643.2	.2000	2.18	.9912	10.79	1.7200	18.72	
1030.3	.4300	2.92	1.5900	10.80	2.6500	18.00	
797.5	.3000	2.63	1.2325	10.82	1.8000	15.80	
599.8	.2800	3.27	.9275	10.82	1.6000	18.67	
2049.1	.8000	2.73	3.1750	10.85	5.8000	19.81	
939.0	.2000	1.49	1.4563	10.86	2.7000	20.13	
955.2	.2500	1.83	1.4825	10.86	2.7000	19.79	
507.5	.2000	2.76	.7894	10.89	1.2000	16.55	
582.5	.3400	4.09	.9081	10.91	1.2000	14.42	
851.1	.1500	1.23	1.3275	10.92	2.0500	16.86	
532.7	.5000	6.57	.8312	10.92	1.1500	15.11	
948.4	.1900	1.40	1.4856	10.97	2.5000	18.45	
1049.3	.5000	3.34	1.6438	10.97	2.9000	19.35	
966.6	.2000	1.45	1.5300	11.08	2.7000	19.55	
710.1	.1500	1.48	1.1325	11.16	2.0000	19.72	
576.4	.1100	1.34	.9212	11.19	1.5500	18.82	
779.3	.4500	4.04	1.2500	11.23	2.2000	19.76	
525.6	.2000	2.66	.8531	11.36	1.3500	17.98	
1158.4	.5000	3.02	1.8875	11.41	3.4000	20.55	
907.4	.1500	1.16	1.4813	11.43	2.5400	19.59	
539.0	.2000	2.60	.8800	11.43	1.3500	17.53	
515.7	.2000	2.71	.8500	11.54	1.3000	17.65	
517.1	.1300	1.76	.8538	11.56	1.2500	16.92	
1055.2	.1500	1.00	1.7500	11.61	3.2500	21.56	
1291.1	.2500	1.36	2.1506	11.66	4.1500	22.50	
642.6	.2000	2.18	1.0750	11.71	1.7000	18.52	
698.4	.1500	1.50	1.1719	11.75	2.3000	23.05	
840.7	.2500	2.08	1.4125	11.76	2.5000	20.82	
1681.9	.1000	.42	2.8325	11.79	4.5000	18.73	
790.3	.1500	1.33	1.3313	11.79	2.0000	17.71	
1368.1	.1000	.51	2.3063	11.80	4.1000	20.98	
618.0	.2500	2.83	1.0438	11.82	1.6000	18.12	
842.0	.3000	2.49	1.4231	11.83	2.4000	19.95	
501.1	.1100	1.54	.8581	11.99	1.5500	21.65	
853.3	.2000	1.64	1.4688	12.05	2.3000	18.87	
1043.5	.2000	1.34	1.7969	12.05	2.9000	19.45	
693.0	.1500	1.52	1.1938	12.06	2.0500	20.71	
620.2	.3500	3.95	1.0688	12.06	1.8000	20.32	
614.1	.1900	2.17	1.0588	12.07	1.9000	21.66	
1110.1	.4000	2.52	1.9313	12.18	3.1000	19.55	
599.9	.3500	4.08	1.0450	12.19	1.8000	21.00	
554.1	.6000	7.58	.9719	12.28	1.2500	15.79	
1023.7	.1200	.82	1.7988	12.30	3.1000	21.20	
667.4	.4500	4.72	1.1750	12.32	1.7000	17.83	
726.9	.1900	1.83	1.2800	12.33	2.1000	20.22	
753.8	.5600	5.20	1.3288	12.34	1.8500	17.18	
583.5	.6000	7.20	1.0313	12.37	1.3500	16.20	
1031.6	.4000	2.71	1.8281	12.40	3.3000	22.39	
920.1	.1500	1.14	1.6575	12.61	2.9500	22.44	

**FRAGMENT WEIGHT-PRESENTED AREA DATA
FOR TEST NO. QD-155-08
(2nd FIRING)**

Polar Zones 0°-180°

No. of Frags Selected for Measurements = 231

Frag Wt (Grains)	Presented Area (in. ²)		Average Area	Gamma (in. ² /lb)	Maximum Area	Gamma (in. ² /lb)
	Minimum Area	Gamma (in. ² /lb)				
603.5	.3000	3.48	1.1000	12.76	1.9500	22.62
656.7	.1000	1.07	1.2031	12.82	2.1500	22.92
541.2	.1000	1.29	.9937	12.85	1.9000	24.58
574.9	.1000	1.22	1.0563	12.86	1.9000	23.13
519.6	.2900	3.91	.9612	12.95	1.7000	22.90
608.6	.2000	2.30	1.1313	13.01	2.1000	24.15
546.5	.2500	3.20	1.0181	13.04	1.8000	23.06
713.3	.3500	3.43	1.3344	13.09	2.2500	22.08
567.8	.1000	1.23	1.0625	13.10	1.8600	22.93
554.4	.1000	1.26	1.0438	13.18	1.5000	18.94
689.2	.4500	4.57	1.3019	13.22	1.9000	19.30
890.1	.3000	2.36	1.7000	13.37	2.9500	23.20
712.0	.1500	1.47	1.3619	13.39	2.2500	22.12
534.1	.2000	2.62	1.0250	13.43	1.7500	22.94
1089.5	.2000	1.28	2.1000	13.49	3.0000	19.27
1044.9	.3000	2.01	2.0156	13.50	3.4000	22.78
525.0	.1500	2.00	1.0188	13.58	1.9000	25.33
547.4	.1000	1.28	1.0775	13.78	1.8200	23.27
528.3	.1500	1.99	1.0400	13.78	1.7500	23.19
566.4	.0200	.25	1.1400	14.09	2.1500	26.57
831.9	.2000	1.68	1.6750	14.09	3.2000	26.93
677.2	.2500	2.58	1.3750	14.21	2.3500	24.29
563.0	.2000	2.49	1.1625	14.45	1.9000	23.62
565.9	.1500	1.86	1.1844	14.65	2.2000	27.21
517.3	.1200	1.62	1.0838	14.67	2.0000	27.06
737.9	.3000	2.85	1.5500	14.70	2.6500	25.14
882.6	1.6000	12.69	1.8625	14.77	2.4000	19.03
719.3	.1500	1.46	1.5225	14.82	2.6500	25.79
669.9	.2000	2.09	1.4219	14.86	2.5000	26.12
507.6	.2000	2.76	1.0850	14.96	1.9200	26.48
699.9	.2500	2.50	1.5188	15.19	2.5000	25.00
596.8	.2000	2.35	1.3063	15.32	2.2000	25.80
606.8	.1000	1.15	1.3438	15.50	2.2000	25.38
662.2	.1000	1.06	1.4775	15.62	2.5500	26.96
542.6	.1000	1.29	1.2200	15.74	2.2100	28.51
571.5	.2000	2.45	1.3438	16.46	2.0000	24.50

FRAGMENT HAZARD INVESTIGATION

Test Number: QD-155-4R

Item Tested: M107 155mm Projectile containing 15 lb of TNT explosive and equipped with a modified M564 nose fuze.

Number of Firings and Dates: 1 - 4 November 1976

Number of Items per Firing: 4

Location of Test: NSWC/DL - Experimental Explosive Area

Arena Configuration: Polar Arena

Fragment Recovery - 0°-180° polar by 11° azimuthal

Fragment Velocities - 0°-180° polar by 27° azimuthal

Projectile Orientation: Four projectiles in a horizontal position; two projectiles stacked on top of the other two projectiles, with their centerlines seven inches apart forming a cube.

Meteorology:

4 November 1976

Barometric Pressure - 29.95 in. Hg

Temperature - 55°F

Instrumentation: Fragment Velocities - Five high speed motion picture cameras with black and white film.

Documentation - Two high speed motion picture cameras with color film.

Post Test Comments: A well defined fragment jet approximately 7° azimuthal by 65° polar formed in the Celotex and witness panels.

**FRAGMENT VELOCITIES AVERAGED
FOR TEST NO. QD-155-4R**

Polar Zone (deg)	Avg Frag Velocity* (ft/s)
0- 5	3872.98
5- 10	4366.34
10- 15	3648.42
15- 20	2500.00
20- 25	3012.05
25- 30	**
30- 35	**
35- 40	**
40- 45	**
45- 50	**
50- 55	4118.64
55- 60	4348.27
60- 65	5173.91
65- 70	5641.82
70- 75	6379.08
75- 80	6932.44
80- 85	7294.51
85- 90	7557.45
90- 95	8483.85
95-100	8020.65
100-105	7652.22
105-110	7378.60
110-115	7652.22
115-120	**
120-125	**
125-130	2696.56
130-135	3901.48
135-140	1945.53
140-145	1893.94
145-150	**
150-155	2057.61
155-160	2087.55
160-165	4215.38
165-170	3428.56
170-175	4881.96
175-180	5022.65

*Velocities recorded at 25.0 ft stand-off

**Instrumentation failure

**FRAGMENT WEIGHT AND NUMBER TOTALS COMBINED FOR
POLAR ZONES 0°-180° OF TEST NO. QD-144-4R**

<u>Weight Group (Grains)</u>	<u>No. of Frag</u> s	<u>Total Weight</u>
.1- 100.0	2904.0	32171.1
100.0- 300.0	240.0	41680.2
300.0- 500.0	84.0	32242.7
500.0- 600.0	25.0	13601.8
600.0- 700.0	21.0	13493.8
700.0- 800.0	22.0	16339.5
800.0- 900.0	15.0	12731.4
900.0-1000.0	15.0	14062.8
1000.0-1200.0	25.0	27246.5
1200.0-1400.0	15.0	19421.3
1400.0-1700.0	14.0	21311.1
1700.0-2000.0	14.0	25962.6
2000.0-2500.0	0.0	19435.7
2500.0-3000.0	5.0	13738.9
3000.0 +	6.0	24808.3

FRAGMENT HAZARD INVESTIGATION

Test Number: QD-155-10R

Item Tested: M107 155mm Projectile containing 15 lb of TNT explosive and equipped with a modified M564 Nose Fuze.

Number of Firings and Dates: 1 - 2 February 1977

Number of Items per Firing: 4

Location of Test: NSWC/DL -- Experimental Explosive Area

Arena Configuration: Azimuthal Arena

Fragment Recovery -- 90° to 110° polar
75° to 105° azimuthal
345° to 375° azimuthal

Fragment Velocity -- 90° to 110° polar
150° to 210° azimuthal
240° to 300° azimuthal

Projectile Orientation: Four projectiles vertically positioned with all centerlines seven inches apart forming a cube.

Meteorology:

2 February 1977 Barometric Pressure -- 29.31 in. Hg
Temperature 60°F

Instrumentation: Fragment Velocity -- Five high speed motion picture cameras with black and white film.

Documentation -- Two high speed motion picture cameras with color film.

Post Test Comments: Fragment concentrations formed at all desired locations; 0°, 90°, 180°, and 270° azimuthal angles.

**AVERAGE FRAGMENT VELOCITIES PER AZIMUTHAL ZONE
FOR EACH POLAR ZONE OF TEST NO. QD-155-10R**

ZONE (DEG) POLAR

AZIMUTHAL**	Velocity (ft/s)*			
	<u>90-95</u>	<u>95-100</u>	<u>100-105</u>	<u>105-110</u>
300-290	4213.4	3714.4	2814.9	1694.9
290-280	3939.9	3802.5	3338.5	3424.7
280-270	4206.4	4347.8	3377.6	3521.1
270-260	6406.4	6353.8	6651.5	6598.8
260-250	5042.6	4422.7	3534.8	4192.4
250-240	3031.1	3046.5	3977.5	3623.2
240-230	3715.6	3461.6	3035.1	2155.2
210-200	4433.0	3972.2	2488.9	2350.0
200-190	4149.2	3968.1	3572.4	2302.4
190-180	4571.9	5156.8	4846.7	5592.2
180-170	6818.3	7196.3	7552.7	7364.5
170-160	5661.1	5373.6	5747.1	5385.0
160-150	4310.3	4807.7	4464.3	4587.2
150-140	2173.9	2164.5	2155.2	2083.3

*Velocities recorded at 25.0 ft stand-off

**Projectile interaction areas located at 90° and 180° azimuthal angles

**FRAGMENT RECOVERY DATA FOR TEST NO. QD-155-10R
(FRAGMENT WEIGHT AND NUMBER TOTALS)**

AZIMUTHAL*	ZONE (DEG) POLAR 90-95		95-100		100-105		105-110	
	FRAG NO.	FRAG WT.	FRAG NO.	FRAG WT.	FRAG NO.	FRAG WT.	FRAG NO.	FRAG WT.
352-354	**	---	---	---	11	1866.5	16	1733.7
354-357	97	10043.4	76	10341.7	76	9780.9	73	14959.9
357-0	105	6973.8	106	11371.5	75	21397.8	89	13901.1
0-3	82	2487.5	60	1831.9	110	9410.8	155	16641.8
3-6	1	1.5	30	1426.6	12	856.8	32	707.7
6-9	7	31.7	6	31.4	9	1888.3	10	1477.2
78-81	**	---	---	---	11	2680.1	23	208.6
81-84	---	---	---	---	28	778.6	70	4267.2
84-87	---	---	---	---	103	9537.9	160	9738.6
87-90	110	7098.9	77	5926.3	79	14428.7	160	20595.5
90-93	164	7345.3	170	10227.8	30	12092.4	44	8989.2
93-96	26	743.3	39	1951.6	17	1699.8	42	4880.6
96-99	18	50.4	13	1614.6	24	2421.4	16	173.9
99-100	8	559.1	4	49.8	5	5.8	11	24.3

*Projectile interaction areas located at 0° and 90° azimuthal angles
 **Fragments were not collected in these zones

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